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ABSTRACT

A study was conducted to determine the effects of sentence length, sentence structure, and word frequency on the readability of textbook prose. Specifically, the study assessed the extent to which the factors, taken alone or in combination, affected the readability of two 1,000-word college textbook passages when the content remained the same. Two existing textbook passages were rewritten to create eight different versions of each passage: one pair of passages was written with a shorter average sentence length than the original, a second pair contained more frequently occurring synonyms substituted for some of the infrequently occurring words in the original, and a third pair was composed of modified sentence structures. The remaining pairs included combinations of these three readability factors. At the first of two sessions, 336 high school seniors read a passage about cells or computers, recorded their reading times, responded to measures of interest and comprehension, then read a second passage. The second passage, on the other topic, was assessed for retention a week later. Results showed that shortening the averaging sentence length, changing the sentence structures, and altering word frequency did not improve the reading efficiency of the students, nor did they affect the students' interest in or their comprehension of the passages. (Author/FL)

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THE EFFECTS OF WORD FREQUENCY, SENTENCE LENGTH AND SENTENCE STRUCTURE ON THE READABILITY OF TWO COLLEGE TEXTBOOK PASSAGES

by

Linda L. Johnson

Report from the Project on
Studies in Language: Reading and Communication

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THE EFFECTS OF WORD FREQUENCY, SENTENCE LENGTH AND SENTENCE STRUCTURE ON THE READABILITY OF TWO COLLEGE TEXTBOOK PASSAGES

Linda L. Johnson

Under the Supervision of Professor Wayne Otto

ABSTRACT

The purpose of this study was to determine the effects of three stylistic factors on the readability of textbook prose. The three stylistic factors were sentence length, sentence structure and word frequency. The study was intended to assess the extent to which the factors, taken alone or in combination, affected the readability of two 1000-word college textbook passages when the content remained the same. Readability was defined as the fluency with which a prose passage is comprehended.

Researchers have found that word frequency and sentence length are associated with the difficulty of short passages intended for children. These factors need to be examined further to determine how much they might be responsible for the difficulty of textbooks intended for mature readers. A third factor, sentence structure, was also examined for its effects on readability. Sentence structure has been suggested in three recent readability theories as a cause of

difficulty.

To assess the effects of the three stylistic factors on textbook readability, two college textbook passages were rewritten with shortened sentences, more frequently occurring nontechnical words, and cumulative sentences, those sentences containing a short base clause followed by free modifiers. Combinations of the three variables formed the remaining treatment conditions. The comprehension, rate, reading efficiency and retention of high school seniors were assessed on the original passages and on their rewritten versions. Reading efficiency, the number of comprehension test items answered correctly per minute of reading time, was used for the main measure of readability. The comprehension assessment consisted of short answer, wh-questions constructed from randomly selected outline statements.

At the first of two sessions conducted at four high schools, 336 subjects read a passage about Cells or Computers, recorded their reading times, responded on measures of interest and comprehension, then read the second passage. The second passage, on the other topic, was assessed for retention a week later. The data was primarily analyzed using Kruskall-Wallis planned comparisons.

When the mean scores of the original versions were contrasted with the rewritten versions, the scores fell into patterns that may warrant further investigation, although the statistical tests did not reach statistical significance. The Cells passage seemed easier when rewritten with the combination of short sentences and more frequently occurring words and when rewritten with the combination of all three

stylistic factors. The Computer passage seemed easier when rewritten with sentence structure alone or in combination with other factors.

The results were thought due to the differences in the actual causes of difficulty in the original passages. To the degree that difficulties in the original passages were corrected in the rewritten versions, readability was likely to be improved. Although some difficulties in the original passages--lengthy base clauses and unfamiliar nontechnical vocabulary--were corrected, the likely overwhelming cause of difficulty, unfamiliar content, was not corrected, resulting in nonsignificant differences in readability.

Wayne R. Otto

I

RATIONALE, HYPOTHESES AND QUESTIONS

The purpose of this study was to determine the effects of three factors on the readability of representative college textbook selections. Two of the factors, sentence length and word frequency, appear in almost all of the most widely used readability formulas. The third factor, sentence structure, is a candidate for inclusion in new readability formulas. The study was intended to assess the extent to which the factors, either singly or in combination, affect the readability of two 1000-word textbook passages. Results of the study were intended to indicate whether existing readability formulas are appropriate for textbooks and whether the three factors are applicable for writing easier textbooks.

Readability refers to the degree of fluency with which a group of readers comprehend a prose passage. Highly readable materials are comprehended rapidly, without frequent rereadings or pauses to determine the meaning. Highly unreadable materials are comprehended only with difficulty and delay, if they are comprehended at all.

In order to examine the effects on readability of the three stylistic factors, two existing textbook passages were rewritten to create eight different versions of each passage. Each of one pair of passages was written with a shorter average sentence length than found in the original textbook passage. A second pair of passages contained more frequently occurring synonyms substituted for some of the infrequently occurring words in the original passages. A third pair of passages was composed of modified sentence structures. The remaining pairs of

passages included combinations of these three readability factors. The eight types of passages are listed below:

Original
Word Frequency
Sentence Length
Sentence Structure
Word Frequency--Sentence Length
Word Frequency--Sentence Structure
Sentence Structure--Sentence Length
Word Frequency--Sentence Structure--Sentence Length

After the original passages were rewritten, judges evaluated all passages for changes in meaning. Then short-answer wh-questions were composed from randomly selected statements of the text. The comprehension questions were developed following procedures suggested by Bormuth (1970) and Anderson (1972). An eight-item interest measure was also constructed. Twelfth grade college-bound students read the pairs of passages and responded on measures of comprehension, interest, rate, and retention.

Since passages requiring extra time to comprehend are less readable according to the above definition of readability than are passages requiring little time, both rate and comprehension were measured in the present study. The rate and comprehension scores were combined to create a reading efficiency measure. Subjects who comprehended the passage only after spending considerable time were given a lower reading efficiency score than subjects who spent little time but comprehended the passage just as well.

Interest and retention were examined in the study because readability, or comprehension ease, is not the only factor that should be

considered in writing or evaluating textbook prose. If textbook material is very hard to understand, both interest and retention may be affected. Interesting points may be missed because readers have to work too hard to understand, and retention may be difficult because readers have little understanding of what they have read. On the other hand, easy material may permit readers to relax enough to take an interest in what they read and to understand well enough to recall it.

While it is unlikely that interest would be adversely affected by improved readability or by manipulating any of the stylistic factors, retention could be adversely affected. If readers were able to breeze through material without needing to consider the meaning, they might forget what they had read. Since textbook material is intended to be retained, perhaps the price of improved readability would be too high. Retention and interest should not be neglected in any research on the readability of textbooks.

RATIONALE

Textbook readability has concerned educators for many years, and much research has been done on the effects of text difficulty on comprehension and learning. Some researchers have related the difficult readability of college textbooks to drop-out rates and to decreased learning (Kurzman, 1974; Cline, 1973; Wiegand, 1967). Yet highly readable textbooks may be so unchallenging that students may show less growth in vocabulary and reading ability than shown by students using more challenging texts. Chall (1977) related the readability level of

textbooks to Scholastic Aptitude Test (SAT) scores. She found that in years of declining SAT scores, students had been using easier textbooks during their schooling, while the reverse was true for years of high SAT scores. For students, then, the readability levels of textbooks must be finely adjusted. Students using texts which are either too hard or too easy may learn less than if they used texts between these two extremes.

Matching students with suitable textbooks, while important, is not easy. Readability formulas are often applied to textbooks to help with this matching process. Readability formulas are used to assign grade level estimates to samples of prose. The applicability of readability formulas to textbooks, however, has been questioned frequently (Froese, 1971; Brown, 1965; Maxwell, 1978). Moreover, the overall validity of formulas has been challenged over the years (Taylor, 1953; Bormuth, 1966; Pearson, 1974-75). If valid formulas especially designed for textbooks were developed, assigning appropriate textbooks to students would be facilitated.

An examination of procedures for developing readability formulas indicates how formulas can be improved and how they can be validated for textbooks. Formulas are constructed by correlating quantifiable language factors with passages which have been graded in difficulty. Quantifiable language factors might be sentence length, number of prepositional phrases, word frequency, and word length, among others. The graded passages are short, about 100-200 words in length. They are ranked in difficulty by finding the mean scores of children who read the passages and answer multiple-choice questions about them or who fill in cloze

blanks of the passages. The two or three language factors correlating highest with the passages are included in the formula.

The resulting readability formula should be applied to similar passages intended for similar children. The greater the dissimilarity between the criterion passages and the passages to which the formula is applied, the greater the invalidity of the formula for those passages. When a formula so developed is applied to lengthy textbook passages intended for college students, its validity becomes highly questionable. Yet, instructions for such readability formulas provide grade equivalent scores for materials at high school and college levels, and the formulas are applied to textbook passages at these levels in many research studies.

Even if readability formulas were applied only to reading selections that were similar to the criterion passages, the formulas would not estimate their readability very well. The correlations between language factors included in the most used formulas and passage difficulty amount to no more than .70 (Dale & Chall, 1948; Flesch, 1948; Gunning, 1964; McLaughlin, 1969; Fry, 1968). Consequently, no more than half of the comprehension score differences between these passages are explained by the factors used in the readability formulas. The other half may be due to any number of other factors. Correlations might be higher if more predictive language factors were used in place of the easily manipulated ones. Bormuth (1966), for example, obtained .75 and .80 correlations between passage difficulty and such single factors as independent clause length and the number of prepositional phrases per sentence.

Even if language factors were highly correlated with passage difficulty, the validity of resulting formulas would be questionable. Although many language factors are associated with difficulty, those factors most often used in readability formulas have not been shown to actually cause difficulty. Certain reading selections, for example, may contain an unusually high number of short, rare words. Readability formulas with a word length factor may underestimate the difficulty of such passages. If the formulas included factors which were shown to actually contribute to passage difficulty, readability estimates for even unusual passages would be more valid predictors.

Before better readability formulas are constructed, then, research needs to be done to find those language factors that cause readers to experience difficulty in comprehending. After the factors have been identified, those that are also easily measurable may be examined in research to develop readability formulas. So far, causal research has not been very informative for identifying such factors, largely because of methodological problems. Klare (1976) analyzed 36 experimental studies in which passages were rewritten and then compared on various measures of reader performance. He found that numerous extraneous factors raised or lowered the probability of finding significant differences in readers' comprehension of the passages. He identified several factors relating to data-gathering procedures, passage-rewriting techniques, and to the prior knowledge, interests, and reading abilities of the subjects. These factors were considered in designing the present study.

In gathering data, researchers have not always considered the effects of motivation and reading time, according to Klare. If subjects are highly motivated, they may stay with a very difficult passage until they comprehend it, that is, if reading time is not limited. If reading time is not controlled, differences between easy and difficult passages may be obscured. In the present study, subjects were fairly highly motivated to do well, as they were told that their individual scores would be reported to them. Reading time, however, was recorded so that passages requiring extra time to understand were identifiable.

Passages that were fairly low in interest-value were selected because highly interesting passages were expected to motivate subjects to comprehend, even if the passages were difficult. If high interest materials were used, differences in readability would be obscured. Passages selected for use in this study were of medium to low interest value as rated by judges.

Prior knowledge of content may also mask differences in readability. If the information contained in a passage is already well known to readers, the readers are likely to have little difficulty in reading the passage, even if the style is difficult. On the other hand, new information may be understood better if the writing style and vocabulary are easy rather than hard. In the present study, passages were selected on cell biology and computer data processing, topics that differed as to the amount of detailed instruction high school seniors had received. Subjects were asked about their prior knowledge of a topic as part of an interest survey for each passage.

Finally, the readability level of the "difficult" passage must indeed be difficult for the subjects to understand, according to Klare. If subjects attain very high comprehension scores on the "difficult" passage, it is unlikely that they could score even higher on a rewritten version. In the present experiment, entering twelfth grade students read passages intended for first-year college students. The "difficult" passages, then, were expected to be difficult for these subjects to comprehend.

Consideration of the above factors were expected to result in findings caused by the variables under study rather than caused by extraneous factors.

Interest and retention were also assessed in the study. Most of the research on interest has shown that subjects who are interested in what they read tend to comprehend the material better than subjects who are not interested (Estes & Vaughan, 1973). In the present study, interest was a dependent variable: Would improved readability affect the subjects' interest in the passage? In an earlier study (Klare, Mabry, and Gustafson, 1955), an easier writing style resulted in more acceptable reading material than a harder writing style, even when content and technical terms were the same.

Retention may be negatively affected by an easy writing style. If material is easy to read, subjects may read it quickly and retain less information than if they had read a passage requiring careful reading in order to be comprehended. Hiller (1974) concluded that a moderately difficult style coupled with moderately difficult questions stimulated

careful reading. He gave one group of subjects a comprehension test two weeks after they had read a moderately difficult passage. The subjects scored significantly higher on the test than a group who had read a version of the passage shown to be of average difficulty. Although the research examining the affects of improved readability on interest and retention is not extensive, further investigation appears warranted.

The three stylistic factors examined in this study were among many factors involving format, style, organization, and content that could have been selected for further examination. The study was limited to the three stylistic factors because two of them (sentence length and word frequency) were already used extensively in readability formulas, and elements of the third (sentence structure) might be inserted into new readability formulas. Moreover, all three could be manipulated by textbook writers interested in improving readability without appreciably changing the meaning of a technical passage.

Word Frequency

Word frequency has been studied more often than the other two factors, but most of this research supports word frequency only as a factor in the difficulty of individual words. The frequency of a word refers to the number of times it occurs in samples of spoken and written language. High frequency words are easier than low frequency words according to at least four types of research. First, high frequency words are recognized faster than low frequency words. Howes and Solomon (1951) used a tachistocope to flash words of differing frequency

according to the Thorndike-Lorge (1944) frequency count. Subjects' visual duration thresholds were inversely related to frequency. Second, high frequency words can be pronounced faster than low frequency words. Forster and Chambers (1973) used a voice-operated switch to find that high frequency words were pronounced before low frequency words. Third, the difficulty of words on I.Q. tests and standardized vocabulary tests is related to word frequency (Kibby, 1977). The harder words on the tests were less frequent according to the Kučera-Francis (1967) word list, and the easier words were more frequent. Selection of words for the tests was based on the empirical difficulty of each word as determined in preliminary studies. Fourth, high frequency words are recalled better than low frequency words. Sumby (1963) used a recall task in which lists of 15 unrelated words, either high or low in frequency, were recalled by subjects. Overall recall was better for the high frequency words.

In a few studies, word frequency has also been associated with passage difficulty. Correlations of .51 and .54 were obtained by Lorge (1948) and Bormuth (1966) respectively. As short passages became increasingly difficult, the words in the passages became increasingly unfamiliar. The effects of word frequency on the readability of SRA power builders read by sixth grade students was investigated by Marks, Doctorow & Wittrock (1974). The power builders were made significantly easier for sixth grade students to read by substituting frequently occurring synonyms for the unfamiliar words of the original passages. Morrow (1974) and Shaffer (1976), however, found no significant

differences in cloze scores when word difficulty was varied. Research needs to be done to examine whether alterations in word frequency affect the difficulty of textbook prose. It could be that unfamiliar content is the true cause of passage difficulty when infrequently occurring words are present. This question is addressed in Chapter IV.

Sentence Length

The second stylistic factor examined in this study is sentence length. Sentence length is a factor in 22 of the 48 readability formulas cited by Klare (1963, 1974-75). Furthermore, sentence length counts appear in all of the most widely used formulas. Sentence length was shown to be significantly related to passage difficulty in a number of studies. Ojemann (1934), Flesch (1948) and Bormuth (1966), respectively, obtained correlations of .60, .52, and .58 between sentence length and passage difficulty.

Results were mixed in studies in which passages were rewritten with shorter sentences. Coleman (1962) constructed cloze tests of an original passage and of a version rewritten with shortened sentences. He found that university undergraduates filled in the cloze blanks of the version with shortened sentences significantly better than the cloze blanks of the original version, although the difference was very small. Shaffer (1976) obtained similar results with secondary students, but Morrow (1974) found no significant differences with community college remedial reading students. No recent studies were located in which the dependent variable was a comprehension test score rather than a cloze score, though

Klare (1976) cited three older studies in which no significant differences were found. The research thus far is inconclusive as to the role of sentence length in readability. The present study was designed to clarify this role.

Sentence Structure

The sentence structure factor that was manipulated in this study was actually the combination of several syntactic characteristics, only the first two of which have already been examined in the research literature. The rest have been suggested by readability theorists as likely to affect difficulty. The characteristics, followed by the research and theories in support of each, are first listed and explained below:

1. Clause length: The average length in words of independent and dependent clauses. Readability theorists suggest that short clauses contribute to reading ease.

2. Subject--verb--object (S-V-O): The words of a main clause are arranged in this order and with few words separating these main elements.

3. Location of main clause: The main clause is located at the beginning of the sentence whenever possible.

4. Free modifiers: These are modifying words or phrases, set off by commas, which add information about the main clause or its elements. One theorist suggests that free modifiers should follow the main clause whenever possible.

5. Bound modifiers: These modifving words and phrases may not be moved about within the sentence. They tend to lengthen clauses. For this reason, some readability theorists suggest that their number be reduced.

The first of the five syntactic characteristics, clause length, has been found to be a factor in both sentence and passage difficulty. Bormuth (1966) found that clause length was correlated with passage

difficulty as measured by using the cloze procedure. Coleman (1965) created active-verb sentences from sentences with nominalizations, e.g.:

Nominalization:
His explanation of the design...

Active verb:
He explained the design...

Coleman found that subjects required fewer trials to learn the active-verb sentences only when the clause length was also shortened. In an earlier study, Coleman (1964) found significant improvement in the multiple-choice test scores of college students who read 3000-word articles that had been rewritten with active verbs substituted for verbs that were passives, nominalizations, or adjectivalizations. The active-verb transformations resulted in a decrease in average clause length from 15.3 to 8.9 words.

Clause position was not found to affect passage difficulty as measured by cloze and chunk tests administered to ninth grade students (Szabo, 1976). Szabo also separated the subject from the verb of sentences by inserting a subordinate clause. This change, too, did not affect passage difficulty. Coleman (1965), however, found that cloze scores were higher for nonembedded sentences than they were for embedded sentences. As used in the experiment, embedded sentences were identical to sentences with a subordinate clause inserted between the subject and the verb. The following sentences were cited as examples of embedded and nonembedded sentences:

Embedded:
She gave the ring that I found to Jim.

Nonembedded:
She gave Jim the ring that I found.

While the research studies cited above are few in number and conflicting in results, theoretical support for the syntactic characteristics as factors in readability is substantial. Several readability theorists suggest that one or more of the syntactic characteristics may affect difficulty (Palmer, 1974; Fry, 1975; Hirsch, 1975). Moreover, the theorists suggest that sentence length may also affect readability.

Hirsch (1977) concluded that the balance of three factors help produce a readable writing style. Relevant to this study is closure, which refers to short-term memory limitations. Sentences should be worded so that short-term memory is not overburdened. The subject of a sentence, for example, should not be separated from the verb by long embedded phrases because the subject may be forgotten by the time the verb is reached. In the present study, short sentences and clauses were expected to facilitate closure because few embeddings would separate subjects and verbs. Hirsch's other factors were expectancy and integration.

Fry (1975) proposed a Kernel Distance Theory of readability. He suggested that subject-verb-object clusters (kernels) appearing at the beginning of the sentence are easier to read than when they appear elsewhere. Moreover, the number of words separating elements of the kernel affects the difficulty of the sentence. This theory is similar to

Hirsch's concept of closure except in the location of the kernel. Thus, in both theories, embeddings interfere with readability, and short sentences and clauses are expected to be easier to read. The placement of the kernel at the beginning of the sentence was one of the characteristics of sentence structure examined in the present study.

Palmer (1974), citing work by Christensen (1968), suggested that increasing the number of short noun phrases, short clauses, and free modifiers ought to improve readability. Furthermore, decreasing the number of bound modifiers should also improve readability. By writing "cumulative sentences" with the main clause first, followed by modifying clauses, meaning is built on meaning; the sentence becomes more specific as it is read. All of these suggestions were incorporated in the sentence structure condition.

HYPOTHESES AND QUESTIONS

The above theories suggest that rewriting textbook passages so that sentences and clauses are shorter and so that words are more familiar should result in easier textbook passages. Previous research is scanty or inconclusive as to the facilitative effects of these changes. Methodological problems of some of the research may account for the mixed results.

Since readability refers to comprehension ease, not comprehension alone, a comprehension test by itself would not provide a measure of readability. The appropriate measure of readability is the combination

of a comprehension test and a rate measure, to be referred to as reading efficiency.

Reading efficiency is reflected by the amount of time subjects need to spend on a passage to attain a certain comprehension score. Thus a reader scoring 70% comprehension after reading for ten minutes earns a lower reading efficiency score than a reader scoring 70% comprehension after reading for only five minutes. Reading efficiency scores were expected to be higher for those subjects reading any of the rewritten passages than for those reading the original passages:

> Hypothesis 1. Subjects reading passages with a shortened average sentence length will score significantly higher on the reading efficiency measure than subjects reading the original passages.
>
> Hypothesis 2. Subjects reading passages with modified sentence structures will score significantly higher on the reading efficiency measure than subjects reading the original passages.
>
> Hypothesis 3. Subjects reading passages modified through the substitution of more frequent synonyms will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Much research has shown that combinations of factors rather than a single factor by itself are responsible for the readability of a passage (Klare, 1963; Pearson, 1974-75). Morrow (1974), for example, found no significant differences on cloze test performance when either sentence length or word difficulty was varied, but when these were combined, cloze performance was significantly improved. This likely is due to little change in the passage resulting when only one factor is applied but when both factors are applied, a large change results. Changes either in sentence length or in word difficulty may have resulted in improved cloze

scores if the changes had been extensive enough. Shaffer (1976) found that shortening sentences and substituting easier synonyms resulted in significantly higher cloze scores than either alone, but shortening sentences still resulted in significantly higher cloze scores than the original passage. In the present study, changes in the original passages were expected to have a cumulative positive effect:

> Hypothesis 4. Subjects reading passages in the eight treatment conditions will obtain mean reading efficiency scores that rank from lowest to highest as follows:
>
> Original
> Word Frequency
> Sentence Length
> Sentence Structure
> Word Frequency--Sentence Length
> Word Frequency--Sentence Structure
> Sentence Structure--Sentence Length
> Word Frequency--Sentence Structure--Sentence Length

Synonym substitution of frequent for infrequent words was expected to result in less improved readability than the other two factors. Accurate synonyms for technical vocabulary rarely exist. For this reason, nearly all substitutions were made for nontechnical vocabulary, and the effects of these changes were expected to be relatively minimal. Changes in sentence structure were expected to result in greater improvement in readability than changes in sentence length because the changes were expected to be more extensive.

Interest and retention, two important considerations in evaluating and writing textbooks, may be affected if the readability is improved. Since little research has been done on these factors, questions rather than hypotheses were stated.

Greater interest may result if a passage is read more efficiently. If a passage is very difficult, readers may be so concerned with comprehending that they may fail to recognize information that otherwise would be interesting to them. Thus passages found to be easier than the original were also expected to be found more interesting. The following question refers to this relationship:

> Question 1. Will the same subjects reading passages that result in higher reading efficiency scores also achieve significantly higher interest scores than subjects reading the original passages?

Interest, then, may be increased either because the passage itself becomes more interesting or because increased comprehension efficiency permits readers to recognize interesting information which was present all along.

Retention of passage information is essential for learning from textbooks. No benefits would be produced if improved readability resulted in less retention. On difficult passages, however, subjects need to spend more time reading and thinking in order to understand the information. On easier passages, they need to spend less time. According to past research, the more time readers spend on a passage the better it is recalled (McConkie & Rayner, 1974). Thus, efficient processing of prose may result in less retention. On the other hand, prose that is difficult to process may be incompletely understood no matter how much time is spent on it. This relationship is expressed in the following question:

> Question 2. Will subjects reading the original passages score significantly higher on the retention measure than subjects reading the significantly easier passages?

Findings regarding the above four hypotheses and two questions were intended to indicate the effects of the three stylistic factors on readability as determined by the efficiency score, and on interest and retention.

II

METHOD

Word frequency, sentence length and sentence structure were varied in the experiment in order that their effects on readability, interest and retention could be examined. Word frequency was varied through synonym substitution, the changing of infrequently occurring words to their more frequently occurring synonyms. Sentence length was shortened to an average of twelve words as suggested by findings of Marckworth and Bell (1967). Sentence structure was altered by shortening clause length and rearranging phrases within the sentences while keeping the average sentence length about the same. Combinations of these factors formed the other treatment conditions.

SUBJECTS

Subjects selected for the study were 336 high school twelfth grade students from two rural and two suburban high schools in southern Wisconsin. Students in English or social studies classes at the schools were randomly assigned to the eight treatment conditions. The number of students from each school is listed in Table 1.

Table 1

Participants in the Experiment by School

School	Number of Seniors
A	118
B	101
C	73
D	44

MATERIALS

The materials used in the experiment consisted of two college textbook passages and seven rewritten versions of each. The measurement instruments consisted of two short-answer comprehension tests and an interest survey.

Passages

Two 1000-word college textbook passages were selected from textbooks used in courses open to first-year college students attending the University of Wisconsin. The original textbook passages, then, were expected to be somewhat difficult for the high school seniors to read, a factor suggested by Klare (1976).

College textbooks were selected for the study because they are intended for mature readers, adults who are at a developmental stage in

which grammatical forms need not be simplified because of the readers' ages. The language of the textbooks, except for technical vocabulary and new concepts and principles, might be found in general magazines and newspapers intended for adults.

Certain types of textbooks were eliminated from consideration in selecting the textbook passages. Those textbooks used in courses for which prerequisites were listed were not considered. Furthermore, the 1000-word passages were selected from only the first two chapters of the books. These restrictions lessened the need for students to have considerable background knowledge as a prerequisite for comprehending the material. So that only expository prose which is uninterrupted by equations, formulas and diagrams would be selected, narrative, mathematics, music and similar textbooks were eliminated from consideration.

Readability was also considered in selecting the textbooks. The first two chapters of the selected textbooks were examined for readability with a computerized version of the Dale-Chall Readability Formula (Dale & Chall, 1948). The two highest-scoring and two lowest-scoring texts were eliminated. Although the validity of readability formulas has been questioned, formulas do permit the text selections to be ranked similarly in average sentence length and in percentage of unfamiliar words as determined by the formula. These factors are associated with the difficulty of short passages.

Passages in the first two chapters of the remaining eight textbooks were chosen to conform to certain criteria. All passages began at a section heading and did not end abruptly after approximately 1000 words.

Diagrams or equations did not interrupt content within the passages. No references were made in the passages to figures, diagrams or to information already given in earlier sections of the text.

The nine passages that were selected according to these criteria were reevaluated using the Dale/Chall Readability Formula. Next, they were examined by eight doctoral students in reading. The students ranked the passages twice. First the students ranked the passages from most to least difficult, according to their own judgments of the causes of difficulty. Then the students ranked the passages according to their interest in the passages. The students also determined for each passage whether sentence length, sentence structure or vocabulary contributed most to its difficulty. The two passages that were rated most similar in Dale/Chall readability and in the rankings determined by the students were selected for the study. The forms filled out by the doctoral students are presented in Appendix A.

The two passages which were finally selected were similar in interest and readability according to the doctoral students' rankings and according to the readability formula results. These similarities are summarized in Table 2.

The interest ranking is the mean rank in interest as evaluated by the doctoral students. The students ranked nine passages according to their interest in them, ranking the two passages that were finally selected about the same. The interest score was determined in a pilot study of fifteen graduate students in reading, a study in which the interest measure for the present experiment was developed. The graduate students read only one of the two passages and rated it on the fifteen

Table 2

Readability Scores and Interest Appeal of the Original Passages

Score	Cells Passage	Computer Passage
Number of words	1011	992
Dale/Chall grade equivalent	13-15	13-15
raw score	9.0	9.21
average sentence length	19.4	23.1
precentage unfamiliar words	27.8	27.8
Interest ranking*	4.8	4.6
Interest score**	3.3	3.4

*Possible range was from 1 to 9.
**Possible range was from 1 to 7.

items of the interest measure. The items consisted of seven-point semantic differential scales (See Appendix B). Results indicated no significant difference in interest (P = .89). Moreover, both passages were rated below the mid-point of four on the scales, signifiying they were of low to medium interest value. The interest measure pilot study will be discussed further in the measuring instruments section of this chapter.

Although the original passages were similar in several ways, other differences prevented the two passages from being analyzed together. The

content of the passages, for example, was quite dissimilar. The "Cells" passages concerned plant and animal cells. A discussion of the history of human knowledge about plant and animal cells was followed by an analysis of similarities and dissimilarities in cellular structure and function. Finally, a type of bacterial cell was described. Students who had studied biology might already be somewhat familiar with the general topic of cells. The "Computers" passage, by contrast, concerned the functioning of a computer, comparing it with the operation of a tape recorder. Most students would very likely have little knowledge of the specific operations of either machine at the level described in the passage. These differences in familiarity were confirmed by results of a measure of background knowledge included on the interest survey in the main study.

After the passages were selected, certain procedures were followed to make changes in sentence length, sentence structure and word frequency. These procedures are detailed in the next three sections.

Sentence Length

In four of the rewritten versions of each passage, the average sentence length was shortened. Sentence length variations among passages are presented in Table 3.

The Dale-Chall readability formula was applied to each passage to show that the rewritten versions were easier according to conventional measures of readability. Since the percentage of unfamiliar words is weighted more heavily than sentence length in the formula, differences in

Table 3

Average Sentence Length and Readability of Passages Altered By Shortening Sentences

Passage	Number of Words	Number of Sentences	Ave.Sent. Length	Dale/Chall Scores
Cells				
Original	1011	52	19.4	9.00 13-15
Sentence Length	1049	88	11.9	8.72 11-12
Sent. Length & Word Frequency	1054	88	12.0	8.29 11-12
Sent. Length & Sent. Structure	1054	79	13.3	9.11 11-12
Sent. Length & Sent. Structure & Word Frequency	1060	79	13.4	8.47 11-12
Computer				
Original	992	43	23.1	9.21 13-15
Sentence Length	1072	85	12.6	8.72 11-12
Sent. Length & Word Frequency	1072	85	12.6	8.36 11-12
Sent. Length & Sent. Structure	1007	68	14.8	8.97 11-12
Sent. Length & Sent. Structure & Word Frequency	1011	68	14.9	8.73 11-12

the readability scores between the original passages and their rewritten versions are smaller than what might otherwise be expected.

In rewriting the original passages with shorter sentences, a few other changes resulted. Rewritten passages had fewer compound and complex sentences. Moreover, the rewritten passages contained a greater number of words and sentences than the original passages. On the other hand, the ordering of words and sentences in the rewritten passages resembled the ordering of the original passages as much as possible. See Appendices C and D for the four sentence length passages as read by the subjects.

Sentence Structure

In contrast to the sentence length conditions where only periods and extra words were inserted, many substantial changes were made in the sentence structure conditions. The average sentence length was increased slightly, while words and phrases within the sentences were rearranged to create cumulative sentences with short base clauses. In expository writing, cumulative sentences consist of a main idea followed by free modifiers or explanatory details. Free modifiers are explanatory sentence elements which are usually set off by commas.

A cumulative sentence:

> The curriculum is at best, however, a design to be interpreted by teachers, for children--by teachers with varying degrees of ability and insight, for children with differing equipment in intelligence and language background (Northrop Frye, cited in Christensen, 1979).

Christensen splits this sentence into two levels, a base clause followed by two free modifiers:

1 The curriculum is at best, however, a design to be

interpreted by teachers, for children--

2 by teachers with varying degrees of ability and insight

2 for children with differing equipment in intelligence and language background.

While the base clause is not particularly short in this example, the important elements, subject, verb and object, are very close together. In the following example, free modifiers, or explanatory details, may be subordinate to other free modifiers:

1 Instead, they (the schoolroom grammars) dealt with bits and pieces of the English language--

2 those bits where native speakers disagreed among themselves,

3 so that a choice among conflicting customs had to be made. (James Sledd, cited in Christensen, 1979).

In the examples, free modifiers are located after the base clause, but in other sentences, free modifiers may be located elsewhere. In this study, free modifiers were positioned whenever possible after the base clause. The base clause was shortened by relocating other modifiers when possible. While most sentences were modified in some way, such as being joined with other sentences, noticeable or startling language was avoided. See Appendices C and D for the four sentence structure passages as they were presented to the subjects. Table 4 summarizes the structural and syntactic differences among the passages.

As shown in Tables 3 and 4, changes in sentence length and sentence structure were combined in two of the treatment conditions. The two combination versions consisted of the sentence structure conditions

Table 4

Sentence Characteristics of Passages
Altered in Sentence Structure*

Passage	Cumulative Sentences		Ave. Clause Length	
	one Free Mod.	>1 Free Mod.	Base Clause	Free Modifier
Cells				
Original	18	8	11.5	7.1
Sentence Structure	17	19	9.3	8.1
Sentence Structure & Word Frequency	17	19	9.3	7.8
Sentence Structure & Sentence Length	21	6	9.4	5.8
Sentence Structure & Word Frequency & Sentence Length	20	7	9.5	5.8
Computer				
Original	17	3	17.0	7.7
Sentence Structure	10	16	9.5	9.5
Sentence Structure & Word Frequency	10	16	9.6	9.5
Sentence Structure & Sentence Length	19	5	9.4	7.4
Sentence Structure & Word Frequency & Sentence Length	19	5	9.6	7.6

*See Table 6 for Dale/Chall scores.

altered by shortening their sentences. In making these shortened sentences, frequently only one free modifier remained attached to the base clause. Moreover, many sentences were left with no free modifiers at all. The combination of sentence length and sentence structure, then, usually resulted in shorter sentences, many with short base clauses and a single free modifier.

Word Frequency

Synonyms were substituted for infrequently occurring words in four treatment conditions. The Kucera-Francis word list (1967) was consulted to determine the frequency of occurrence of each word appearing in the original passages. Those words occurring fewer than 100 times per million were eliminated whenever a higher frequency word could be substituted. The main form of the word rather than the inflected form was used for determining the frequency of a word. In this way, a greater number of words could be substituted. Technical words were not changed as adequate substitutes could not be found for these words. Word characteristics of the original passages are summarized in Table 5. The words and their substitutions are listed in Appendix E.

As the Table 5 shows, about one-fourth of approximately 1000 words in the passage occurred 100 or fewer times per million but only about half of these words were nontechnical. Still fewer of the nontechnical words were actually changed because adequate synonyms were seldom found.

So that more words could be changed, synonyms were substituted even if they appeared only slightly more frequently on the Kucera-Francis list than appeared the original words of the passage. The substituted words were still unfamiliar on the Dale list used in the Dale-Chall formula, so

Table 5

Word Frequency Characteristics of the Original Passages

Characteristic		Cells	Computer
Number of words		1011	992
Words occurring 100 or fewer times per million	types*	151	84
	tokens**	259	218
Number of technical words	types	60	32
	tokens	145	103
Technical words occurring 100 or fewer times per million	types	53	22
	tokens	145	91
Nontechnical words occurring 100 or fewer times per million	types	98	62
	tokens	114	127
Number actually changed (suitable synonyms found)	types	52	32
	tokens	65	50

*Types are different words.
**Tokens include repetitions of different words.

again little change was made in the difficulty according to that formula. Readability formula results for all passages are shown in Table 6.

A total of sixteen passages were created, the two original textbook selections and the fourteen rewritten versions, two for each treatment condition. One paragraph from each of the two original passages is shown in its eight different versions in Appendix F.

Table 6

Readability Formula Scores
For All Passages

Passage	Ave. Sent. Length	% Unfamiliar Words	Raw Score	Dale/Chall Score
Cells				
Orig	19.4	27.8	9.00	13-15
WF	19.6	24.5	8.53	11-12
SL	11.9	28.5	8.72	11-12
SS	20.8	29.5	9.50	13-15
WF & SL	12.0	26.0	8.29	11-12
WF & SS	20.9	26.2	8.80	11-12
SL & SS	13.3	30.5	9.11	13-15
WF & SL & SS	13.4	26.7	8.47	11-12
Computer				
Orig	23.1	27.8	9.21	13-15
WF	23.1	25.5	8.93	11-12
SL	12.6	28.4	8.76	11-12
SS	26.3	27.4	9.53	13-15
WF & SL	12.6	26.0	8.36	11-12
WF & SS	13.4	26.1	9.16	13-15
SL & SS	14.8	29.1	8.97	11-12
WF & SL & SS	14.9	27.0	8.73	11-12

Orig = Original WF = Word Frequency SL = Sentence Length
SS = Sentence Structure

To ensure that substantial changes in meaning did not result, three doctoral students in reading compared all rewritten passages with the original versions to locate changes in meaning. Wherever the doctoral students discovered changes in meaning, sections were rewritten. Only a few minor corrections were required.

The passages were rewritten according to specifications from past readability research and from the theories of readability specialists. Data obtained from measures of reading rate, comprehension, retention,

and interest were interpreted to discover whether past research and theories were applicable for textbook readability. Instruments created to obtain the data are described in the following section.

Measurement Instruments

Two types of measurement instruments were constructed for the study. On one, a set of semantic differential scales, subjects rated their interest in a passage. On the other, a comprehension test, subjects wrote short answers to wh-questions. The comprehension score obtained from the test was combined with rate to yield a reading efficiency score.

Comprehension Tests

The two comprehension tests were constructed after the two original passages were rewritten. This sequence prevented the tests from influencing the wording of the passages. Procedures were developed for selecting units of meaning to be tested and for constructing the actual test items from these units of meaning.

To select main ideas and details for testing, outlines of both textbook passages were constructed. The outlines were reconstructed three months later and compared for differences. The infrequent differences concerned placement of ideas on the proper level of the outline, not the ideas, themselves. Placements usually differed only by one level. Final outlines are located in Appendix G.

The two outermost levels of the outline were designated as main ideas; the remaining levels were details. The main ideas are labeled with Roman numerals and capital letters in the outlines in Appendix G.

The outlines of the two passages produced the following quantities of main ideas and details:

	Cells	Computers
main ideas	48	47
details	50	49

The main ideas and details of each passage were then listed separately and divided into fifteen nearly equal sections. One idea was randomly selected from each section and turned into one or more wh-questions, following procedures suggested by Bormuth (1970) and Anderson (1972). From each selected sentence, questions were worded using synonyms which were not found in any of the rewritten passages. A few questions were deleted from each set so that the comprehension test used in the pilot study consisted of 24 items, twelve main ideas and twelve details. Deletions of questions were made when sentences were turned into questions which duplicated other questions and answers. Deletions were also made when questions indicated answers to other questions.

After the tests were constructed, a pilot study was conducted to eliminate poor items and test the procedures used in the study. Students in a twelfth grade reading class read either the two original textbook passages or the two passages which incorporated all three factors--sentence length, sentence structure, and word frequency. Results of the pilot study are summarized in Table 7.

The efficiency measure indicated the number of correct comprehension test items per minute of reading time. Comprehension items were scored

Table 7

Mean Scores for the Original and Rewritten Passages Obtained by Students in the Pilot Study

	N	Comprehension	Words per minute	Efficiency	Interest
Cells Passage					
Original	9	5.6	214.8	1.3	29.4
Rewritten	11	7.7	216.0	1.6	27.4
Computer Passage					
Original	11	5.0	221.0	1.1	23.7
Rewritten	13	5.9	241.5	1.4	26.1

by comparing the answer given by the subject with the word or phrase that was changed into a wh-question. Acceptable synonyms and paraphrases were decided upon ahead of time. When other acceptable synonyms or paraphrases were found in scoring the answers, they were added to the list of acceptable answers. An example of a statement from the outline, a question and its acceptable answers follow:

Statement:

The smallest living organisms are composed of single cells.

Question:

What are the smallest living organisms made of?

Answers:

a single cell, single cells, a cell, one cell, cell

Although no significant differences were found between the original passages and their rewritten versions, the means of all scores but one, (the "Cells" interest score of 27.4), were in the predicted direction. The small number of subjects in each cell may have prevented significant results.

The 24-item comprehension tests proved to be difficult, as was indicated by the low mean scores in Table 7. An item analysis was performed to eliminate the most difficult and the easiest items. Six items from each test were eliminated, one because nearly all of the subjects got it right, the rest because fewer than 25% of the subjects got them right and the items could not be changed without interfering with other items. Most of the remaining questions were rewritten, employing the same statements used in constructing the original items. The tests were shortened to 18 questions, nine main ideas and nine details apiece. The final version of the tests can be found in Appendix H.

Interest Survey

The interest survey was constructed by finding antonyms related to interest and placing them at opposite extremes of seven-point semantic differential scales. Subjects were to mark on the scales their degree of interest in the passage they had just read. Examples of items are "interesting--uninteresting" and "boring--fascinating." A group of fifteen graduate students in reading completed a fifteen-item version of the survey after reading either of the two original passages. Eight of the items correlated at .80 or above in a factor analysis of the survey. The high correlation indicated that the eight items were assessing very nearly the same idea, which appeared to be interest. These eight items were selected for the survey used in the main experiment as well as in the pilot experiment. Three additional items were constructed to measure the subjects' assessment of their own prior knowledge and interest in the subject of each passage. The final version of the test can be found in Appendix I.

After the measurement instruments were evaluated and revised, data for the main experiment were collected according to the procedures described in the next section.

PROCEDURES

The experiment was conducted at four high schools during the last two weeks of September, 1979. During the first of two sessions, the twelfth-grade subjects read two passages, both from the same treatment condition, and took the comprehension test for the first passage and the

interest surveys for both passages. During the second session, one week later, they took the comprehension test for the second passage.

At the beginning of the first session, materials were distributed randomly to the subjects so that each treatment condition was equally likely to be distributed during a class period. Materials for each condition were stapled and paper-clipped together. Subjects received one of the following arrangements of their passages:

Cells Comprehension	Computer Comprehension
Cells Passage	Computer Passage
Interest Survey	Interest Survey
Comprehension Test	Comprehension Test
Computer Passage	Cells Passage
Interest Survey	Interest Survey
Note--Explains absence of Comprehension Test	Note--Explains absence of Comprehension Test

In mixing the order of presentation of the two textbook passages, both comprehension and retention could be measured. Since only half of the subjects of a given treatment condition took the comprehension test of either the "Cells" passage or the "Computer" passage, the treatment conditions were doubled to 16, a Cells Comprehension and a Computer Comprehension for each of the eight pairs of passages. The sixteen cells were filled with subjects from each school as shown in Table 8.

After the materials were distributed to a class of students, directions (Appendix J) were read orally and any questions were answered at that time. Subjects were also shown how to read a digital clock provided by the examiner and how to record their starting and ending times in minutes and seconds. Subjects began reading the first passage at the same time. After they had completed the passage, they recorded

Table 8

Number of Subjects in Each Treatment Condition

	Cells Comprehension (Computer Retention)	Computer Comprehension (Cells Retention)
Original Passages	21	17
Word Frequency	19	24
Sentence Length	19	21
Sentence Structure	20	21
Word Freq. & Sent. Length	23	22
Word Freq. & Sent. Struc.	23	22
Sent. Length & Sent. Struc.	21	23
Word Freq. & Sent. Length & Sent. Struc.	19	19

their ending times and raised their hands as they began responding to the interest survey for the passage. The first passage was then collected so that the subjects could not refer back to it when they came to the comprehension test.

Upon completing the comprehension test for the first passage, subjects turned to the second passage, recorded their starting time, and began reading. When they completed the second passage, they recorded

their ending time and began the interest survey while again raising their hands. The second passage thereupon was collected. After completing the interest survey, subjects turned the page for the second comprehension test. Instead of the comprehension test, however, they found a note (Appendix K) stating that for their particular part of the experiment, the comprehension test would be given a week later. After everyone had completed all of the experimental materials, the remaining materials were collected.

One week later, the second part of the experiment was conducted. Only the comprehension test of the second passage was distributed to the subjects. Subjects were asked to recall on the comprehension test what they had read a week earlier. On a still later date, a sheet with the individual subject's scores was distributed to each subject. The results were interpreted and discussed in class.

ANALYSIS OF DATA

The eight treatment conditions were the independent variables. The dependent variables were rate, comprehension, interest, retention, and efficiency. One efficiency score was obtained by combining rate and comprehension, and another was obtained by combining rate and delayed comprehension (retention). The efficiency score was the number of correct answers on the comprehension test per minute of reading time. A subject who scored 10 correct answers after taking 360 seconds to read would attain an efficiency score of 1.67, a little over one and one-half correct answers per minute of reading time. Since the combined results of such a measure were ratios with unknown distributions, nonparametric

statistics were employed. For all hypotheses and questions involving efficiency, planned comparisons involving the Kruskal-Wallis nonparametric analogue to one-way analysis of variance were used. For the questions and hypotheses involving interest and retention, the parametric one-way analysis of variance was used. When any of the parametric tests were significant, the conservative post-hoc Scheffe's test was used to reveal which means were significantly different from one another.

III

RESULTS AND DISCUSSION

The purpose of this study was to examine the effect of three stylistic factors on the readability of textbook prose. Twelfth grade students at four high schools read versions of two textbook passages, recorded their reading time, and responded to measures of interest and to measures of immediate and delayed comprehension. Before the results are examined with regard to the four hypotheses and two questions, analyses of the comprehension tests and interest survey are reported.

COMPREHENSION TESTS

The two comprehension tests, one for the Cells passages and one for the Computer passages, had been revised in view of results of the pilot study reported in Chapter II. Items were rewritten or deleted on the basis of an item analysis. The resulting comprehension tests had 18 short-answer items, nine main idea questions and nine detail questions.

Reliability

Cronbach alpha reliability coefficients were computed for the tests, using SPSS, the Statistical Package for the Social Studies (Nie, et al., 1975). Cronbach's alpha is perhaps the most widely used reliability

coefficient (Nie & Hull, 1977). Since the comprehension test data were dichotomously scored, the alpha reliability coefficients are equivalent to another widely used reliability coefficient, the Kuder-Richardson-20. The reliability coefficients, determined separately for comprehension and retention uses of the tests, are reported in Table 9.

Table 9

Reliability Coefficients for the Cells and Computer Short-Answer Tests

Test	Cells		Computer	
	n	alpha	n	alpha
Comprehension	165	.66	167	.74
Retention	157	.61	156	.60

Although tests with reliability coefficients in the observed range of .60 to .74 are not totally satisfactory for examining differences among individual students' scores, they are satisfactory for determining differences among group means (Thorndike, 1971).

Passage Dependency

Passage dependency was assessed in order to determine the degree to which the test items could be answered without reading the passage. To determine passage dependency, one group of twelfth grade students was

given the comprehension tests without the accompanying passages. This test-only group of subjects consisted of two twelfth grade classes from a school whose students scored higher in background knowledge and interest in the Cells passage than students at the other schools. The test-only subjects were challenged to try to outscore the subjects who had read the passage.

In analyzing the data, each comprehension test item was evaluated by comparing the percentage of correct answers achieved by the test-only group with the percentage of correct answers achieved by the subjects of the main experiment. The ten items that discriminated the most between the two groups were selected for a reanalysis of the data. The item analyses are presented in Tables 10 and 11.

Similar results were obtained using the high discriminating items. When results were significant using the 18-item tests, they were also significant using the the 10-item tests. When results were not significant with the 18-item tests, they were also not significant with the 10-item tests.

Yet the 10-item tests seemed more passage dependent than the 18-item tests. The aforementioned differences among schools in background knowledge and interest in the Cells passage was also found in comprehension of the Cells passage. Subjects in some schools scored significantly higher ($f = 3.091$, d.f. $= 3/160$, $P < .03$) on the 18-item comprehension test of the Cells passage than subjects in other schools. Subjects in these same high-scoring schools also scored significantly higher ($f = 7.354$, d.f. $= 3/330$, $P < .0001$) in background knowledge than

Table 10

Difficulty of the Cells Test Items for the
Test-Only Group and for the Experimental Subjects

Item	Main Idea (M) or Detail (D)	Experimental % Correct	Test-Only % Correct	Difference
1	M	.84	.76	.08
* 2	M	.52	.24	.28
3	D	.11	.00	.11
* 4	D	.45	.29	.16
* 5	D	.52	.00	.52
6	D	.38	.71	-.33
7	M	.89	.82	.07
8	M	.75	.76	.01
9	D	.02	.00	.02
*10	D	.22	.06	.16
*11	M	.81	.41	.40
*12	M	.31	.18	.13
13	M	.77	.76	.01
14	D	.04	.06	-.02
*15	D	.23	.06	.17
*16	M	.60	.24	.36
*17	D	.42	.00	.42
*18	M	.29	.06	.23

*Items selected for the passage dependent analyses.

subjects in the other schools. Higher comprehension scores for these schools would be expected if prior knowledge as well as ability affected the results. When only the 10 passage dependent items were included,

Table 11

Difficulty of the Computer Test Items for the Test-Only Group and for the Experimental Subjects

Item	Main Idea (M) or Detail (D)	Experimental % Correct	Test-Only % Correct	Difference
* 1	M	.70	.53	.17
* 2	M	.47	.18	.29
* 3	M	.67	.35	.32
* 4	D	.23	.06	.17
* 5	M	.26	.00	.26
6	M	.79	.88	-.09
* 7	D	.24	.06	.18
* 8	M	.09	.00	.09
* 9	M	.40	.06	.34
*10	D	.44	.00	.44
11	D	.54	.47	.07
*12	M	.17	.00	.17
13	D	.30	.35	-.05
14	M	.04	.06	-.02
*15	D	.40	.35	.05
16	D	.07	.06	.01
17	M	.16	.12	.04
18	D	.07	.06	.01

*Items selected for the passage dependent analyses.

however, no differences among the schools were found. This result leads to the conclusion that passage dependency had been increased.

Since all other results did not differ between the 10-item and 18-item versions of the tests, the original 18-item version was retained for reporting the data analysis of the study.

Main Ideas and Details

The objective of the comprehension tests was to assess the subjects' recall of main ideas and details that they had read. In order to identify main ideas and details in the passages, outlines were prepared. The outlines consisted of five levels (labeled I, A, 1, a, (1), etc.), moving inward from important, general, or topical statements to the innermost, least important and most detailed statements. The two outer levels of the outline statements were defined as main ideas and the rest of the outline statements were defined as details. If this distinction actually existed--if the outline had been constructed properly--then the main ideas ought to be recalled better than the details (e.g., Meyer, 1975). To determine any difference in the recall of main ideas and details, the percentage of correct main idea answers and the percentage of correct detail answers were computed for each subject. In a matched pairs t-test, the mean main idea percentages of correct answers were compared with the mean detail percentages of correct answers. Results are reported in Table 12.

Main ideas were recalled significantly better than details. Thus, some validity was established for the outlines that were constructed.

As shown in Table 12, the percentage of correct answers for the main idea and detail questions is very low. Difficult items were produced

Table 12

Percentage of Correct Main Idea and Detail Items Obtained by the Subjects

	Main Idea	Detail	P
Cells			
Comprehension	.64	.27	<.01
Retention	.53	.16	<.01
Computer			
Comprehension	.37	.29	<.01
Retention	.32	.25	<.01

because of two factors in the test construction process. Main idea items were selected from the two outermost levels of the outline rather than from the one outermost level. Subjects might not have recognized the second level of statements as very significant and worth remembering. A similar factor may have affected the difficulty of the detail questions. Some of the detail questions were selected from the innermost few statements, those statements of greatest detail and perhaps seen by readers as least important.

The second factor affecting item difficulty is the task readers need to perform when answering wh-questions. In constructing a wh-question, a

word or phrase is deleted from a statement and replaced by a suitable wh-word. The test-taker must recall the deleted word or phrase or suitable synonyms. As the wording of the questions is different from that of the original statements because of the substitution of synonyms, the reader is assumed to be relying on comprehension as well as recall in answering the questions. Nevertheless, readers must be able to recall what they read very literally in order to obtain correct answers. Wh-questions are very difficult because of this heavy reliance on fairly exact recall.

Reliability coefficients, passage dependency, and validity for the two comprehension tests were sufficiently satisfactory so that statistical tests of the differences between group scores on the tests were interpretable.

INTEREST SURVEY

As reported in Chapter II, the original 15-item interest survey was revised after a pilot study in which graduate students in reading education read passages and marked semantic differential scales according to their interest in the passage. As a factor analysis of their answers indicated, the subjects tended to mark eight of the items in the same way. All eight items, correlated at .8 or above in the analysis, seemed to be assessing interest, and were selected for the final interest survey. Following the data-collection of the main study, Cronbach alpha reliability coefficients of .94 for the Cells passages and .93 for the Computer passages were determined.

In the next sections, tests related to each hypothesis and question are reported and discussed. Although the first three hypotheses dealt with one stylistic factor, the data is reported with that factor in combination with the other stylistic factors as well as alone. To direct the reader's attention to the stylistic factor under discussion, the factor is underlined in the table.

HYPOTHESIS 1

A positive effect of sentence length on the readability of textbook prose as determined by the reading efficiency score was predicted by the first hypothesis. Subjects reading the passages with shortened sentences were expected to comprehend those passages more efficiently than subjects reading the original passages.

> Hypothesis 1: Subjects reading passages with a shortened average sentence length will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Four passages about cells and another four passages about computers contained shortened sentences:

Sentence Length
Sentence Length & Word Frequency
Sentence Length & Sentence Structure
Sentence Length & Word Frequency & Sentence Structure

These passages formed four treatment conditions for each original passage. A reading efficiency score was computed for the subjects in each treatment condition. The efficiency score was obtained by calculating the number of correct comprehension questions scored by a subject per minute of reading time. The mean efficiency scores earned by

the subjects of the sentence length treatment conditions are presented in Table 13.

The mean efficiency scores are displayed to show the very slight differences in efficiency obtained by subjects who had read the five different versions of the passages. These mean scores, however, were not needed to perform the two Kruskall-Wallis planned contrasts which were used to test the hypothesis. Instead, mean ranks were computed for each treatment condition. These were calculated by ranking all reading efficiency scores from highest to lowest and assigning a numerical rank to each score. The ranks for the 165 subjects who read the Cells passage first, for example, ranged from 1 to 165. Once the ranks were established, the subjects' ranked scores were divided once more into the original eight treatment groups. The mean rank for each treatment group was then computed. The mean ranks of the five groups compared for the sentence length hypothesis are also reported in Table 13.

The planned comparison for the Cells passage contrasted the combined mean ranks of the four sentence length conditions with the mean rank of the original Cells passage. The difference between the two mean ranks was divided by the standard error of the difference in average ranks of the two groups. The result of these two computations was a Z score. To obtain the standard error of the difference, the variances of the two ranks were summed. The variances had been divided by the number of subjects in their respective treatment group. These procedures are summarized by the following formulas:

$$Z = \frac{\bar{R}_1 - \bar{R}_2}{\sqrt{SE^2_{\bar{R}_1 - \bar{R}_2}}}$$

where $$SE^2_{\bar{R}_1 - \bar{R}_2} = \frac{\sigma^2_{RANKS}}{n_1} + \frac{\sigma^2_{RANKS}}{n_2}$$

where $$\sigma^2_{RANKS} = \frac{N(N + 1)}{12}$$

N = combined sample size from all groups in the ANOVA;

$\bar{R}$ = mean rank

$\sqrt{SE^2_{\bar{R}_1 - \bar{R}_2}}$ = standard error of the difference in average ranks.

Dunn's table for planned comparisons, Table A-1 in Marascuilo and McSweeney (1977), was used for finding the significance of the Z score of .799 that was obtained for the Cells passages from the above formulas. Since this number is smaller than 2.69, which corresponds to infinite degrees of freedom for a one-tail test with a .05 significance level, the Z score did not reach significance. The Z score for the Computer passages was obtained in the same way. That Z score, .018, also did not reach significance.

The mean ranks for the sentence length versions without the combined versions was also contrasted with the mean ranks of the original

Table 13

Mean Reading Efficiency Scores and
Mean Ranks for Subjects Reading the Sentence
Length Passages and the Original Passages

Treatment Condition	Cells n	Cells mean score	Cells mean rank	Computer n	Computer mean score	Computer mean rank
Original	21	1.4	79.7	17	1.0	74.0
Sentence Length	19	1.4	87.6	21	1.0	77.1
Sentence Length & Word Frequency	23	1.6	106.2	19	.9	64.2
Sentence Length & Sentence Structure	21	1.1	64.4	23	1.1	83.7
Sentence Length & Word Frequency & Sentence Structure	19	1.5	96.8	18	1.2	92.8

passages. The Z score of .522 for the Cells passages and .199 for the Computer passages did not reach the significance level of 2.69.

Since neither of the combined mean ranks of the sentence length passages was significantly different from the mean rank of its original passage, Hypothesis 1 was not accepted. Shortening the average sentence length of these textbook passages did not significantly improve reading efficiency. Reading efficiency has been defined in this study as a measure of readability; sentence length, then, did not improve the readability of these textbook passages. This finding is consistent with results of three earlier studies cited by Klare (1976) in which the

dependent variable was a comprehension test score. In these studies, no effects on comprehension were found when the average sentence length was shortened. The finding is also consistent with the results of a study by Morrow (1974), in which the dependent variable was a cloze score. In Morrow's study, cloze scores were not affected by sentence length. The finding is not consistent, however, with results of studies by Coleman (1962) and Shaffer (1976), in which the researchers also used cloze scores as dependent variables. In these studies, the researchers found that cloze scores were higher for passages with shortened sentences, although Coleman noted that the effect was small.

When evaluated separately, the two components of reading efficiency, comprehension and rate scores, were similarly unaffected by sentence length. Mean scores for these dependent variables are reported in Table 14. Since comparisons among the treatment groups were not planned, one-way analyses of variance were performed. The ANOVAs included all eight passages--the word frequency, sentence structure, and word frequency & sentence structure passages, in addition to the original and four sentence length passages listed in Table 14. The Cells and Computer ANOVAs, presented in Tables 15-18, show no significant treatment effect on comprehension or rate.

Thus, sentence length did not affect the reading efficiency, comprehension test scores, or rates obtained by the subjects of this experiment. These findings are consistent with results of certain studies in which a variety of prose passages were rewritten with short

Table 14

Mean Comprehension and Rate Scores
For Subjects Reading the Sentence
Length and Original Passages

Treatment Condition	Rate in Words Per Minute $\bar{X}$	Rate in Words Per Minute s.d.	Comprehension Raw Score $\bar{X}$	Comprehension Raw Score s.d.
Cells				
Original	167.5	36.6	8.2	3.2
Sentence Length	165.8	34.9	8.5	2.3
Sentence Length & Word Frequency	172.1	43.5	9.8	2.2
Sentence Length & Sentence Structure	160.2	30.0	7.2	3.5
Sentence Length & Word Frequency & Sentence Structure	178.2	42.5	8.7	3.0
Computer				
Original	169.8	40.3	5.2	3.0
Sentence Length	170.7	33.1	5.7	3.3
Sentence Length & Word Frequency	182.2	45.0	4.8	3.1
Sentence Length & Sentence Structure	169.0	32.0	6.2	3.1
Sentence Length & Word Frequency & Sentence Structure	182.0	39.1	6.4	3.4

Table 15

Analysis of Variance of Subjects' Comprehension Scores on the Eight Stylistic Variations of the Cells Passage

Source	d.f.	MS	F	P
Between Groups	7	15.287	1.877	.077
Within Groups	157	8.145		
Total	164			

Table 16

Analysis of Variance of Subjects' Comprehension Scores on the Eight Stylistic Variations of the Computer Passage

Source	d.f.	MS	F	P
Between Groups	7	9.796	.95	.47
Within Groups	159	10.310		
Total	166			

sentences. On the other hand, the results are inconsistent with findings of two recent studies in which the dependent variables were cloze scores.

The inconsistency of the findings of the present study with those of the two cloze studies should be examined further. Sentence length may affect cloze scores while not affecting other measures of comprehension. One possible explanation for this effect is that cloze may be a better

Table 17

Analysis of Variance of Subjects' Reading Rate on the Eight Stylistic Variations of the Cells Passage

Source	d.f.	MS	F	P
Between Groups	7	1408.419	.943	.473
Within Groups	325	1493.062		
Total	332			

Table 18

Analysis of Variance of Subjects' Reading Rate on the Eight Stylistic Variations of the Computer Passage

Source	d.f.	MS	F	P
Between Groups	7	1134.175	.556	.791
Within Groups	325	2039.273		
Total	332			

measure of reduncancy, or predictability, than it is of comprehension. If so, sentence length may affect predictability while not affecting comprehension. The increased predictability of short sentences rewritten from a long sentence is shown in the following example:

Original long sentence:

> The President of the United States, in accordance with the protocol established for the office, enters a large formal gathering to the musical strains of "Hail to the Chief."

Rewritten as two shorter sentences:

> The President of the United States enters a large gathering to the musical strains of "Hail to the Chief." He does this in accordance with the protocol established for his office.

The addition of the three underlined words to the second sentence is not likely to cause the passage to be easier to read. Yet, any of the three words would be easy to guess if it were replaced by a blank. The percentage of correctly filled cloze blanks is likely to increase for such passages because of the increase in the number of predictable words. A larger cloze score may result even if the rest of the passage does not increase in predictability. Because cloze scores may be improved by the addition of seemingly unimportant but predictable words to the passage when short sentences are created from long sentences, perhaps the cloze procedure should not be used in sentence length studies.

If the results of the two cloze studies are viewed as suggested above, research in support of shortening sentences to increase readability has either questionable validity or is nonexistent. Theoretical support for shortening sentences is also weak. While the three readability theorists cited in Chapter II make no direct predictions regarding sentence length, they do state that the distance in words between important elements in sentences, such as subjects, verbs and objects, should affect readability because of short term memory restrictions. If these elements are separated by many other words and phrases, sentences should be harder to read because readers may forget

one part of the sentence before they complete the next. Short sentences would seem to preclude this from happening. However, short base clauses in otherwise lengthy sentences would also prevent this occurrence. The original sentences of the Cells and Computer passages were long, but since their elements were seldom interrupted by other words and phrases, perhaps the reduction in sentence length had no effect on their readability. Possibly, shortening the sentences of the original passages did not produce improved readability because the original long sentences did not cause readers any difficulty.

HYPOTHESIS 2

The effects of sentence structure on the readability of textbook prose as determined by the reading efficiency score was addressed in the second hypothesis. Subjects reading passages with increased numbers of cumulative sentences with short base clauses were expected to comprehend the passages more easily than subjects reading the original passages.

> Hypothesis 2. Subjects reading passages with modified sentence structures will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Again, four passages about Cells and four passages about Computers formed the four treatment conditions:

Sentence Structure
Sentence Structure & Word Frequency
Sentence Structure & Sentence Length
Sentence Structure & Word Frequency & Sentence Length

The reading efficiency scores were computed and the mean ranks were analyzed using Kruskall-Wallis planned comparisons. Mean scores and mean ranks are reported in Table 19.

Table 19

Mean Reading Efficiency Scores and
Mean Ranks for Subjects Reading the Sentence
Structure Passages and the Original Passages

Treatment Condition	Cells n	Cells mean score	Cells mean rank	Computer n	Computer mean score	Computer mean rank
Original	21	1.4	79.7	17	1.0	74.0
Sentence Structure	20	1.2	73.0	21	1.4	100.4
Sentence Structure & Word Frequency	23	1.3	74.0	22	1.2	86.8
Sentence Structure & Sentence Length	21	1.1	64.4	23	1.1	83.7
Sentence Structure & Word Frequency & Sentence Length	19	1.5	96.8	18	1.2	92.8

As in the sentence length test, the sentence structure mean ranks were combined and compared with the mean rank of the original passage. The Z score for the Cells passages was .269 and the Z score for the Computer passages was 1.312. Neither approached the necessary significance level of 2.69. When sentence structure, by itself, was contrasted with the original passage, the Z scores of -.445 for the Cells passages and 1.69 for the Computer passage were also not significant.

Thus, as neither of the Kruskall-Wallis tests for the sentence structure conditions of the Cells and Computer passages were significant, Hypothesis 2 was not accepted. Writing textbook prose with short base clauses and cumulative modifying clauses did not improve the readability of the two textbook prose passages as determined by the reading efficiency measure. These findings are consistent with those reported by Szabo (1976) who found that comprehension test scores were unaffected by either clause position or the separation of the subject from the verb by a subordinate clause. The findings are also consistent with results obtained by Hittleman and Robinson (1975) who altered sentence structures and simplified nontechnical vocabulary of textbook material. Cloze scores were unaffected by the changes. The results were not consistent with those of Coleman (1964). Subjects in his study who read technical passages with short clauses and active-voice verbs obtained higher multiple-choice test scores than subjects who read the original technical passages containing nominalizations, adjectivalizations, and passive verbs.

Comprehension and rate scores, the two components of reading efficiency, as already reported, did not differ among the passages. The relevant mean scores for the sentence structure passages are reported in Table 20.

The mean efficiency, rate and comprehension scores for those passages modified by the sentence structure factor were in the predicted direction for the Computer passage. Eleven mean scores were higher than the mean scores for the original Computer passage, and only one mean

Table 20

Mean Comprehension and Rate Scores
For Subjects Reading the Sentence
Structure and Original Passages

Treatment Condition	Rate in Words Per Minute X	Rate in Words Per Minute s.d.	Comprehension Raw Scores X	Comprehension Raw Scores s.d.
Cells				
Original	167.5	36.6	8.2	3.2
Sentence Structure	164.7	44.1	7.5	2.6
Sentence Structure & Word Frequency	162.2	40.0	7.7	3.1
Sentence Structure & Sentence Length	160.2	30.0	7.2	3.5
Sentence Structure & Word Frequency & Sentence Length	178.2	42.5	8.7	3.0
Computer				
Original	169.8	40.3	5.2	3.0
Sentence Structure	176.4	73.6	7.0	3.1
Sentence Structure & Word Frequency	174.7	39.3	6.3	3.6
Sentence Structure & Sentence Length	169.0	32.0	6.2	3.1
Sentence Structure & Word Frequency & Sentence Length	182.0	39.1	6.4	3.4

score, for rate, was lower. For the Cells passages, however, many of the mean scores were in the opposite direction. Perhaps this difference is due to the variation in the average base clause length of the two original passages. If Table 4 in Chapter II is consulted, striking differences may be observed in the number of words in the main clauses of the Cells and Computer original passages. In the original Computer passage, the average base clause was 17 words long, while in the original Cells passage, it was only 11.5 words long. When the passages were rewritten, the average base clause was reduced to 9-10 words, a big improvement in the Computer passage but only a very small difference in the Cells passage.

As reported above and in Chapter I, shortened clauses were associated with improved readability in some studies. Moreover, readability theorists suggested that clause length affects readability. Christensen (1967) observed that the writing style of professional authors was characterized by short base clauses and that poor writing was often characterized by long base clauses. Perhaps readability can be improved through manipulating sentence structures only if the sentence structures, as in the Computer passage, are poorly written to begin with. If sentences are already well-structured (according to the readability theories), restructuring them may not result in any readability improvement. The slight but consistent improvement in readability of those Computer passages whose sentence structures were modified, although not statistically significant, suggests that the improvement of poorly written sentence structures may positively affect readability.

Additional speculation as to why the improvement was not greater is presented at the end of this chapter.

To summarize, the results related to the second hypothesis indicate that readability, as determined by the reading efficiency measure, was unaffected by variations in sentence structure. These findings are consistent with those reported by Szabo (1976) and with those of Hittleman and Robinson (1975), but they are not consistent with those reported by Coleman (1964). Consistent, though nonsignificant improvements in rate, comprehension and efficiency for the Computer passage suggest that in some instances shortening the base clause length may affect readability.

HYPOTHESIS 3

The effects of word frequency on passage readability as determined by the reading efficiency score was addressed in the third hypothesis. Subjects reading passages with slightly more frequently occurring words were expected to comprehend those passages more efficiently than subjects reading the original passages containing less frequently occurring words.

> Hypothesis 3: Subjects reading passages modified through the substitution of more frequent synonyms will score significantly higher on the reading efficiency measure than subjects reading the original passages.

As was done in testing the first two hypotheses, four passages about Cells and four other passages about Computers were formed into four treatment groups:

Word Frequency
Word Frequency & Sentence Length
Word Frequency & Sentence Structure
Word Frequency & Sentence Length & Sentence Structure

Reading efficiency scores were computed for the subjects, and the mean ranks of the scores were analyzed using Kruskall-Wallis planned comparisons. Mean scores and mean ranks are reported in Table 21.

Table 21

Mean Reading Efficiency Scores and
Mean Ranks for Subjects Reading the Word
Frequency Passages and the Original Passages

Treatment Condition	Cells n	Cells mean score	Cells mean rank	Computer n	Computer mean score	Computer mean rank
Original	21	1.4	79.7	17	1.0	74.0
Word Frequency	19	1.3	82.3	24	1.0	82.7
Word Frequency & Sentence Length	23	1.6	106.2	19	.9	64.2
Word Frequency & Sentence Structure	21	1.3	74.0	22	1.2	86.8
Word Frequency & Sentence Length & Sentence Structure	19	1.5	96.8	18	1.2	92.8

The word frequency mean ranks were combined and then compared with the mean rank of the original passage. The Z score for the Cells passages was 1.409 and the Z score for the Computer passages was .612. Again, neither score approached the necessary significance level of 2.69.

Z scores were also computed for the word frequency version, alone, contrasted with the original version. The Z score of .176 for the Cells passages and .579 for the computer passages were not significant.

As neither combined mean rank was significantly different from the mean rank for its original passage, Hypothesis 3 was not accepted. Substituting frequently occurring words for their less frequently occurring non-technical synonyms did not improve the readability of the two textbook passages. These findings are not consistent with those obtained by Marks, Doctorow, and Wittrock (1974). In that study, sixth grade students' multiple-choice comprehension test results differed significantly when the students read original or rewritten SRA power builders. In the rewritten versions, 15% of the words were more frequently occurring than those of the original power builders. In the present study, only about 5% were more frequently occurring than those of the original passages. Findings of the present study, moreover, are not consistent with correlational studies showing that word frequency tends to increase as passage difficulty decreases (Lorge, 1948; Bormuth, 1966).

Comprehension and rate scores for the Cells and Computer passages of the word frequency treatment groups are reported in Table 22. As noted earlier, comprehension test scores and rate did not differ significantly among the passages.

According to the present study, reducing the number of infrequently occurring words by 5% did not improve the readability of either passage. Perhaps if 15% of the words had been changed, improved readability would have resulted, as happened in an earlier study (Marks, et al., 1974). On

Table 22

Mean Comprehension and Rate Scores
For Subjects Reading the Word
Frequency and Original Passages

Treatment Condition	Rate in Words Per Minute X	Rate in Words Per Minute s.d.	Comprehension Raw Scores X	Comprehension Raw Scores s.d.
Cells				
Original	167.5	36.6	8.2	3.2
Word Frequency	163.4	35.2	8.0	2.6
Word Frequency & Sentence Length	172.1	43.5	9.8	2.2
Word Frequency & Sentence Structure	162.2	40.0	7.7	3.1
Word Frequency & Sentence Length & Sentence Structure	178.2	42.5	8.7	3.0
Computer				
Original	169.8	40.3	5.2	3.0
Word Frequency	171.4	44.9	6.0	3.0
Word Frequency & Sentence Length	182.2	45.0	4.8	3.1
Word Frequency & Sentence Structure	174.7	39.3	6.3	3.6
Word Frequency & Sentence Length & Sentence Structure	182.0	39.1	6.4	3.4

the other hand, the technical words, usually rated as very infrequently occurring, are likely to be the most difficult. As long as these words remain unchanged, little readability improvement can be expected. Readability improvement of technical material will be discussed at the end of this chapter.

To summarize, the statistical tests used to determine the effects of word frequency on the readability of two textbook passages did not show a significant difference in reading efficiency for subjects reading the original as opposed to the rewritten versions. No significant improvement in readability resulted when word frequency alterations were made alone or in combination with the other stylistic factors.

HYPOTHESIS 4

Reading efficiency scores for both sets of passages were expected to rank from lowest to highest in line with the extent of change made to the passages. Subjects reading the original passages were expected to have the lowest reading efficiency scores and those reading the combination of all three stylistic changes were expected to have the highest reading efficiency scores. Subjects reading the word frequency passages were expected to differ least from those subjects reading the original passages because few alterations were made to their passages. Subjects reading the sentence structure passages were expected to differ most from those subjects reading the original passages because many alterations were made to their passages. This hypothesis was stated as follows:

Hypothesis 4. Subjects reading passages in the eight treatment conditions will obtain mean reading efficiency scores that rank from lowest to highest as follows:

Original
Word Frequency
Sentence Length
Sentence Structure
Word Frequency--Sentence Length
Word Frequency--Sentence Structure
Sentence Structure--Sentence Length
Word Frequency--Sentence Structure--Sentence Length

In Table 23, the types of passages are ranked according to their obtained mean comprehension efficiency scores. The mean scores were reported in Tables 13, 19, and 21. Tests for monotonic trends on the ranks in the Kruskall-Wallis model were performed to compare the Cell passage efficiency ranking with the predicted ranking and to compare the Computer passage efficiency ranking with the predicted ranking. The Z statistics of .161 for the Cells and .923 for the Computer were not significant when compared with 1.645, corresponding to a one-tail test with a .05 significance level. As a result, Hypothesis 4 was not accepted.

Although Hypothesis 4 was not accepted, the rankings produced by the mean comprehension efficiency scores deserve some comment. In the Computer ranking, as already discussed, sentence structure versions of the Computer passage were always ranked among the easier passages. In the Cells ranking, the combination of word frequency and sentence length (as well as word frequency, sentence length and sentence structure) was ranked among the easier passages. The Cells passage results are consistent with studies cited earlier (Morrow, 1974; Shaffer, 1976) in

Table 23

Predicted and Actual Rankings of Passages by Lowest to Highest Mean Comprehension Efficiency Scores

	Predicted in Hypothesis 4	Cells	Computer
1	Orig	SL & SS	WF & SL
2	WF	SS	Orig
3	SL	WF & SS	SL
4	SS	Orig	WF
5	WF & SL	WF	SL & SS
6	WF & SS	SL	WF & SS
7	SL & SS	WF & SL & SS	WF & SL & SS
8	WF & SL & SS	WF & SL	SS

Orig = Original, WF = Word Frequency, SL = Sentence Length, SS = Sentence Structure

which sentence length or word frequency alone seldom produced significant differences in readability. When they were combined in these studies, significant differences in readability were found. The differences in the effects of the individual stylistic factors on comprehension of the two passages may be due to the differences in the actual causes of the difficulty of the original passages. The actual causes of difficult

readability may need to be assessed directly when rewriting or evaluating prose passages. This point is elaborated on at the end of the chapter.

QUESTION 1

Since little research has been done concerning the effects of increased readability on interest, a question rather than a hypothesis was stated. Interest was expected to be higher for those passages on which significantly higher reading efficiency scores were obtained:

> Question 1: Will the same subjects reading passages that result in significantly higher reading efficiency scores also achieve significantly higher interest scores than subjects reading the original passages?

Since none of the mean reading efficiency scores of the rewritten passages were significantly different from those of the original passages, this question could not be answered. An analysis of variance was performed, however, to see if interest was higher for some versions of each passage than for others. Again, no significant differences were found. The mean interest scores for the passages are presented in Table 24.

QUESTION 2

Another question was asked about the effects of readability on retention. The speculation was that retention might be better for the original passage than for any passages that were found to be read more efficiently than the original passage. Material that is processed

Table 24

Mean Interest Scores of Subjects in Each Treatment Condition

Treatment Condition	Cells Passage $\bar{X}$	Cells Passage s.d.	Computer Passage $\bar{X}$	Computer Passage s.d.
Original	29.6	8.9	29.9	8.3
Word Frequency	32.3	8.0	31.0	7.9
Sentence Length	31.4	7.5	30.4	7.3
Sentence Structure	29.6	8.8	31.1	9.7
Word Frequency & Sentence Length	30.0	10.1	27.3	8.0
Word Frequency & Sentence Structure	31.1	8.8	30.5	6.4
Sentence Length & Sentence Structure	30.3	7.6	29.7	8.3
Word Frequency & Sentence Length & Sentence Structure	29.8	11.7	28.9	10.4

rapidly might not be retained as well as difficult material that must be reread and pondered in order to obtain the meaning.

Question 2: Will subjects reading the original passages score significantly higher on the retention measure than subjects reading the significantly easier passages?

Since none of the comprehension, rate, or efficiency measures indicated that any passage was significantly easier than the original passages, this question, too, could not be examined directly. Instead,

differences in retention efficiency, the combination of rate and the comprehension score achieved after a week's delay, were compared for all passages. The number of comprehension questions answered correctly by subjects per minute of reading time was examined. The Kruskall-Wallis nonparametric analogue to analysis of variance was used to locate any differences among the mean ranks of the passages. Mean scores and mean ranks for the Cells and Computer passages are presented in Table 25.

No effects on retention efficiency were found for either the Cells passages ($\chi^2 = 4.20$, $P = .76$) or the Computer passages ($\chi^2 = 3.19$, $P = .87$). When retention was considered alone, without combining it with rate, results were similar. Mean scores of the subjects' delayed comprehension tests are reported in Table 26. The ANOVA tables for the Cells and Computer passages are in Tables 27 and 28.

None of the four hypotheses constructed for this study were supported; consequently, the two questions could not be answered. No effects on reading efficiency, comprehension, rate, retention efficiency, retention, or interest were found. The stylistic variables under study--sentence length, word frequency, sentence structure, and their combinations--did not have any measurable effect on readability, interest, or retention of these two college textbook passages.

DISCUSSION

Several reasons have already been suggested for the lack of significant differences in the readability of the passages. As indicated, characteristics of the original passage may affect whether

Table 25

Mean Retention Efficiency Scores and
Mean Ranks for Subjects of
Each Treatment Condition

Treatment Condition	Cells Passage n	Cells Passage mean score	Cells Passage mean rank	Computer Passage n	Computer Passage mean score	Computer Passage mean rank
Original	16	1.02	78.25	18	.83	72.44
Word Frequency	22	.96	75.55	17	.99	80.71
Sentence Length	18	.88	68.44	18	.79	73.22
Sentence Structure	19	1.05	85.97	18	1.00	72.64
Word Frequency & Sentence Length	20	.86	71.20	23	1.08	93.48
Word Frequency & Sentence Structure	22	1.07	79.73	21	.90	80.69
Sentence Length & Sentence Structure	23	1.03	84.57	21	.77	70.52
Word Frequency & Sentence Length & Sentence Structure	17	1.10	88.26	19	.88	77.00

certain stylistic changes improve its readability. If the original passage had contained long sentences with major elements separated by many words and phrases, perhaps placing these elements closer together would have improved its readability. If the original passage had contained sentences with extremely long base clauses, perhaps shortening these clauses would have improved its readability. If the original passage had contained many infrequently occurring nontechnical words,

Table 26

Mean Retention Scores (Delayed Comprehension)
For Subjects of Each Treatment Condition

Treatment Condition	Cells Passage X	Cells Passage s.d.	Computer Passage X	Computer Passage s.d.
Original	5.81	2.56	4.94	2.67
Word Frequency	6.27	2.29	5.47	2.40
Sentence Length	5.89	3.10	5.00	2.06
Sentence Structure	6.63	2.48	4.94	2.75
Word Frequency & Sentence Length	5.30	2.70	6.22	2.31
Word Frequency & Sentence Structure	6.77	2.51	4.91	2.02
Sentence Length & Sentence Structure	6.96	2.29	4.86	2.82
Word Frequency & Sentence Length & Sentence Structure	6.23	2.72	4.84	3.04

perhaps substituting frequently occurring synonyms would have improved its readability. The original passages in the present study, however, may not have suffered from any of these difficulties, explaining the lack of effect on readability by any of the stylistic factors.

Another characteristic of the original passages may be more substantially implicated in the lack of significant results. The passages of this study are textbook passages, and textbook passages

Table 27

Analysis of Variance of Subjects' Retention Scores by the Eight Stylistic Variations of the Cells Passage

Source	d.f.	MS	F	P
Between Groups	7	6.241	.942	.476
Within Groups	149	6.625		
Total	156			

Table 28

Analysis of Variance of Subjects' Retention Scores by the Eight Stylistic Variations of the Computer Passage

Source	d.f.	MS	F	P
Between Groups	7	4.959	.778	.606
Within Groups	148	6.371		
Total	155			

generally contain much technical, usually unfamiliar, information. The substantive content of the passages may be the overwhelming cause of any difficulty readers have with such passages. Even if stylistic factors, such as base clause length, were found to be extraordinarily difficult and then were greatly simplified, readers might still find the passages difficult to understand. Unless the difficult content is changed, perhaps by being explained more thoroughly, stylistic factors may have little or no effect. Hittleman and Robinson (1975) made a similar point in discussing the results of their readability study. They suggested that they did not find improved cloze scores on stylistically revised textbook passages because "the concept loads of the passages were so high that simple revisions of the passages did not bring them within the readable range of these particular (ninth grade) students (p. 379-380)."

Conclusions and implications for further research are reported in Chapter IV.

IV

SUMMARY, CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

This study has several implications for readability research, for textbook authors, and for teachers. Before these implications are discussed, a summary, conclusions and limitations are presented.

SUMMARY

The purpose of the study was to determine the effects of three stylistic factors on the readability of textbook material. "Stylistic factors" refers to the writing style of the textbook material rather than to the content or information presented. The three stylistic factors examined in the study were sentence length, sentence structure and word frequency. The study was intended to assess the extent to which the factors, either singly or in combination, affected the readability of two 1000-word college textbook passages when the content was kept the same. Readability was defined as the fluency with which a prose passage is comprehended.

Rationale

Writers, publishers, and educators have been concerned about readability for many years, a concern that has generated much research. Readability formulas have been developed to estimate the level of difficulty of written materials. Moreover, readability theorists have

advised writers and publishers on improving the readability of newspapers, children's books and textbooks.

Matching students with suitable textbooks is essential if students are to learn from these materials. If texts are too hard, students may not be able to understand the information that they are to learn. If texts are too easy, students may not be challenged and may learn less than if they had read harder textbooks.

Matching students with the appropriate textbook, however, is not easy. Textbook selection committees often use a readability formula to estimate the difficulty of textbooks. Formulas, however, have been criticized as inapplicable for textbooks as well as invalid for other written materials. If highly valid formulas were constructed, assigning suitable textbooks to students would be facilitated.

Improved readability formulas would result if factors in their make-up had been shown to affect textbook difficulty as well as the difficulty of other types of prose. The most used readability formulas were developed from correlational studies in which children read many short passages and answered multiple-choice questions about them. The passages were ranked in difficulty according to the children's mean comprehension scores. Researchers found that words and sentences tended to get longer as the passages increased in difficulty. While word length (or frequency) and sentence length (or complexity) were associated with the difficulty of short passages intended for children, these factors need to be examined for their effects on the difficulty of textbook prose intended for mature readers.

Research to identify causal factors in readability has not been very informative. Klare (1976) analyzed 36 readability studies in which passages were rewritten to affect readability. The original and rewritten passages were then compared on various measures of reader performance. Klare found that researchers needed to consider data-gathering procedures, passage-rewriting techniques and the prior knowledge, interests, and reading abilities of the subjects. These factors were considered in designing the present study.

In this study, three stylistic factors previously thought to affect readability were examined. Word frequency differences affected word and passage difficulty in earlier research studies. Moreover, word difficulty factors, such as word frequency, are often used in readability formulas. Sentence length is another factor often found in readability formulas. Past research findings, however, were mixed as to the effects of sentence length on difficulty. Sentence structure, rarely a factor in readability formulas, has been suggested in three recent readability theories as a cause of difficulty. Researchers have found varying results when examining the effects of certain sentence structures on readability.

In the present study, two college textbook passages were rewritten with shortened sentences, more frequently occurring words, and cumulative sentences containing a short base clause followed by free modifiers; combinations of these three variables were also examined. The comprehension and rate of high school seniors were assessed on the original passages and their rewritten versions. Reading efficiency was defined as a measure of readability, as the number of comprehension test

items answered correctly per minute of reading time. Klare (1976) suggested that comprehension measures which took into account reading time were a more sensitive assessment of readability than those that did not.

Interest and retention were also examined. Interest was assessed because researchers have found that improved readability leads to greater interest (Klare, Mabry, and Gustafson, 1955). Retention was checked because it might be affected by improved readability. Researchers have suggested that the longer the time spent on a prose selection, the better it is recalled (McConkie, Rayner, and Wilson, 1973). Retention was tested in the present study to ensure that it was not decreased as a side effect of fluent reading. If readers spent little time on a passage because they did not need to ponder to get the meaning, they might tend to retain less information.

Hypotheses and Questions

Previous research and readability theories tended to support the following hypotheses regarding the effects of the three stylistic factors on readability:

Hypothesis 1: Subjects reading passages with a shortened average sentence length will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Hypothesis 2: Subjects reading passages with modified sentence structures will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Hypothesis 3: Subjects reading passages modified through the substitution of more frequent synonyms will score significantly higher on the reading efficiency measure than subjects reading the original passages.

Hypothesis 4: Subjects reading passages in the eight treatment conditions will obtain mean reading efficiency scores that rank from lowest to highest as follows:

Original
Word Frequency
Sentence Length
Sentence Structure
Word Frequency--Sentence Length
Word Frequency--Sentence Structure
Sentence Structure--Sentence Length
Word Frequency--Sentence Structure--Sentence Length

Two other questions of interest were identified, but since past research and theory were minimal, questions were stated instead of hypotheses.

Question 1: Will the same subjects reading passages that result in significantly higher reading efficiency scores also achieve significantly higher interest scores than subjects reading the original passages?

Question 2: Will subjects reading the original passages score significantly higher on the retention measure than subjects reading the significantly easier passages?

Method

Subjects selected for the study were 336 high school twelfth grade students enrolled in English or social studies classes at two rural and two suburban high schools in southern Wisconsin.

The two college textbook selections on Cells and Computers were from the first chapters of texts being used by first-year students at the

University of Wisconsin. Although the selections were rated equal in difficulty and interest, results were analyzed separately for the two selections because of other possible differences.

The two passages were rewritten to create eight different versions of each passage as follows:

Original
Word Frequency
Sentence Length
Sentence Structure
Word Frequency & Sentence Length
Word Frequency & Sentence Structure
Sentence Length & Sentence Structure
Word Frequency & Sentence Length & Sentence Structure

Sentence length was reduced to an average of 12-13 words in sentence length versions. Word frequency was increased in 5% of the words in word frequency passages. In sentence structure versions, base clauses were shortened, and the number of sentences with more than one free modifier was increased. In the combinations of sentence length and sentence structure, sentences were somewhat longer than in the sentence length version, and there were fewer free modifiers than in the sentence structure version.

Short answer wh-questions were constructed for the Cells and Computer passages by randomly selecting main idea and detail statements from outlines constructed of the passages. These statements were turned into questions by substituting a wh-word for a word or phrase in the statement. The statements were rewritten as questions using, where possible, synonyms not appearing in any of the passages. Questions were reconstructed or eliminated on the basis of an item analysis of pilot

study results. The final 18-item test was used to assess both comprehension and retention.

An interest survey was constructed of antonyms related to interest. The antonyms were placed at opposite extremes of 15 seven-point semantic differential scales. These were reduced to 8 items as a result of a factor analysis performed on data from another pilot study.

At the first of two sessions which were conducted at the four high schools, sets of materials were distributed randomly to the twelfth grade subjects. A subject received a Cells passage and a Computer passage, a comprehension test for one of the passages, and interest surveys for both passages. The Cells and Computer passages were both original versions or both one of the seven rewritten versions. These formed the control and seven treatment conditions. Subjects read a passage, recorded their reading times, and answered the interest survey and comprehension test before proceeding to the second passage. After reading the second passage, they took the second interest survey. A week later the subjects completed the retention test for the second passage.

The data was analyzed using Kruskall-Wallis planned comparisons for Hypotheses 1-3. Tests for monotonic trends on the ranks in the Kruskall-Wallis model was used for Hypothesis 4. One-way analyses of variance were calculated for the two questions.

Results

The two comprehension tests and interest survey were found to have satisfactory reliability and validity, permitting statistical differences between group means to be interpretable. Reliability coefficients

between .60 and .74 were obtained for the comprehension tests and reliability coefficients of .93 and .94 were obtained for the interest survey. An examination of passage dependency was conducted; results did not differ when the ten most passage dependent items were used to analyze the data. Main ideas were recalled more often than details, indicating some validity for the item-selection procedures.

The statistical tests performed for the four hypotheses resulted in no significant differences in reading efficiency among readers of the eight versions of the passages. Moreover, readers of the passages did not differ significantly in interest or retention. Subjects who read the eight versions also did not differ in their comprehension or rate.

Discussion

Although the statistical tests did not reach significance, the mean scores sometimes fell into patterns that may warrant further investigation. The Cells passage seemed be easier when rewritten with the combination of short sentences and more frequently occurring words and when rewritten with the combination of all three stylistic factors. The Computer passage seemed to be easier when rewritten with the sentence structure changes alone or with other combinations which included sentence structure.

The results for the Cells passage, although nonsignificant, were consistent with findings of past research. Combinations of sentence length and word frequency had a greater effect on readability than either alone. These results were not found for the Computer passage unless sentence structure was part of the combination. When the original Cells

and Computer passages were examined, a possible explanation for the somewhat different results was found. The base clauses (main or independent clauses) of the original Computer passage were much longer (17 words) than those of the Cells passage (11.5 words). When the passages were rewritten, the average base clause length was reduced to 9-10 words, a big improvement in the Computer passage but only a very small difference in the Cells passage. The difference in the pattern of results for the Computer and Cells passages may not be due to base clause length alone, however. Christensen (1968) suggested that long base clauses indicated poor sentence structure, or poor writing, and short base clauses were characteristic of professional writers. Poorly written sentences may hinder readability, and when such prose is improved, readability may also be improved. Readability may not have been improved significantly for the Computer passage because its poor sentence structures interfered very little with its overall readability.

The lack of significant differences in readability among the passages may indicate that if readability difficulties of the original passages are not corrected, changes in other readability factors may be ineffectual. If these difficulties, such as lengthy base clauses or unfamiliar vocabulary, are ignored or insufficiently modified, readability may not be improved. The lack of effect in the word frequency conditions is an example. The vocabulary load of the original passages was heavy with technical terms. Findings of previous studies indicate that vocabulary difficulty is highly related to passage difficulty. An important cause of the difficulty of the two passages was very likely the unfamiliar technical vocabulary. These technical words

were not changed because suitable synonyms do not exist. Since the cause of the difficulty was not eliminated, readability was not improved.

According to this reasoning, readability may be enhanced only if the underlying cause of the difficulty is removed. Implications for future research and for textbook authors are discussed later in this chapter.

Textbook prose is similar in many ways, consisting frequently of new terminology and new concepts that need to be explained thoroughly to readers who are likely to be new to the subject being explained. The causes of difficulty in reading this material are likely to be due to such factors as concept load, the rate at which new terms are introduced and repeated, and the thoroughness with which concepts are explained, among other content variables. Stylistic variables, such as sentence length, sentence structure and word frequency, may interfere with the readability of textbook materials. Yet content factors may so override stylistic factors in difficulty, that when style is improved greatly but content factors neglected, little or no measurable readability improvement may result. This is likely the main reason that readability was not improved in the present study.

CONCLUSIONS

The following conclusions are based on the results of the statistical tests of each hypothesis.

(1) Shortening the average sentence length of the two college textbook passages used in this study did not enable twelfth grade readers to read the passages more efficiently--to answer correctly a greater number of comprehension questions per minute of reading time.

Moreover, the readers did not read the passages at a faster rate or answer correctly more comprehension questions than did the readers of the original passages. This result occurred whether sentence length was varied alone or in combination with sentence structure, word frequency or both.

(2) Changes in the sentence structures of the two college textbook passages did not enable twelfth grade readers to read the passages more efficiently. The readers did not read the passage faster or answer more comprehension questions than did the readers of the original passages. When sentence structure was combined with sentence length, word frequency, or both in some passages, differences were still nonsignificant.

(3) Word frequency alterations to 5% of the words of each passage did not help to improve the reading efficiency scores of the twelfth grade students. Furthermore, the subjects did not read the passages at a faster rate or answer more comprehension questions correctly than did readers of the original passages. When word frequency was combined with changes in sentence structure, sentence length, or both, differences were still nonsignificant.

(4) The above changes in sentence length, sentence structure, and word frequency also did not affect the interest that the twelfth grade subjects had in the passage.

(5) The above changes did not affect the delayed comprehension efficiency (retention) of the twelfth grade subjects as measured by the number of correct comprehension items per minute of reading time. Moreover, the changes did not affect the delayed comprehension scores

when they were considered independently of rate. The comprehension tests were administered one week after the subjects had read the passage.

LIMITATIONS

A number of limitations must be kept in mind when interpreting the results of this study.

(1) Klare (1976) reported that readability studies similar to the present one seldom resulted in significant differences among original and rewritten passages unless the original passage was difficult for the subjects to comprehend. If the passage was already readable, increased readability might not affect comprehension scores. The college textbook passages used in this study were assumed to be difficult for the twelfth grade students. The passages were estimated to be at the 13th grade level by the Dale/Chall readability formula. The assumption that they were difficult may not have been valid.

(2) Klare also reported that readability formula scores of original and rewritten versions differed by several grade levels in studies that resulted in significant differences. In the present study, the Dale/Chall formula results of the original and rewritten versions differed by two grade levels or less. Since readability formula findings are questioned in this study, especially for estimating the difficulty of textbooks, perhaps this limitation is inapplicable. Moreover, only two variables can be manipulated to affect Dale/Chall results: sentence length and word frequency. Sentence length could not be reduced further without producing

noticeably awkward language. Word frequency, too, could not be changed further because suitable synonyms were not available for technical vocabulary.

(3) Findings of the present study are limited to twelfth grade readers. If subjects of the study had been children, results might have been very different. Children may find that stylistic features are much more difficult than content in the materials that they read.

(4) Results of the study are limited to the particular textbook prose passages under study. Textbook prose intended for mature readers may be difficult to comprehend for many reasons. If the passages had been difficult because of any of the three factors of this study and were not otherwise difficult, especially in content, significant differences in readability might have been found.

(5) Findings of the present study may have differed if another measure of comprehension had been used. As already discussed, use of the cloze procedure might have produced significant differences in readability for the sentence length passages. Other measures of comprehension might have produced other results. In the present study, short-answer, wh-questions measured the recall of parts of statements randomly selected from outlines of the passages. Recall of parts of statements may not be a valid indicator of comprehension because an inordinately large burden is placed on memory.

(6) The comprehension test items were often very difficult for the students to answer. Six of the Cells items and nine of the Computer items were answered correctly by fewer than 30% of the subjects.

IMPLICATIONS

The results and methods of the present study suggest a number of implications for future research.

(1) Readability theorists have suggested that the three stylistic factors of this study affect prose difficulty. Prior research has also shown that stylistic factors affect readability. Yet the factors did not affect the readability of the two textbook passages of this study. A similar study should be done using nontechnical passages. These might be defined as passages in which nearly all of the difficult vocabulary may be replaced by more frequently occurring synonyms. Perhaps stylistic factors have an effect on nontechnical prose.

(2) Quantifiable content factors in textbook prose should be identified and examined. Results of the present study indicate that stylistic factors may be less important to the readability of textbook prose than other, unidentified factors. Possibly, these factors involve content. Content factors could be identified to quantify how thoroughly new concepts are explained, how often new terminology is introduced, how frequently new ideas are repeated or reinforced.

(3) Children's language development may not be at a point at which children are easily able to comprehend lengthy, complex sentences; adults may experience very little difficulty. If so, sentence length and sentence structure may affect the readability of materials intended for younger children to a much greater degree than they did for the twelfth grade students of this study. Studies similar to the

present one should be done to manipulate sentence variables of prose intended for children.

(4) Results of the present study indicate that readability may be affected by a number of factors which may vary from passage to passage. The long base clauses of the Computer passage were shortened only in the sentence structure versions. Subjects performed consistently better on these versions than on any of the others, although the differences were nonsignificant. Perhaps because the original Cells passage did not have long base clauses, sentence structure changes did not improve its readability. Readability researchers should plan their studies to include more than one passage, ideally several passages from a given type of prose. Otherwise, their findings may be limited to the passage they selected.

(5) The wh-questions constructed to assess comprehension in the study were very difficult for the students to answer because they placed such a heavy burden on memory. Other ways to assess comprehension of a passage should be explored.

The results of this study have implications for textbook writers.

(1) Authors who write textbook selections with short sentences may not significantly affect the readability of material intended for adults. What may be much more important is the clarity of style--good writing--with which content is explained. If textbook authors write logically and clearly, the passage is likely to be readable. Long base clauses with bound modifiers may indicate lack of clarity of expression.

(2) Stylistic factors, however, may not be as important as the content. No matter how short the base clauses and no matter how easy the vocabulary, content factors may override style, interfering with readability. Although the results of this study do not point to content as a factor in difficulty, the likelihood is that content greatly affects difficulty. Writers should be aware of this and work toward making the content easier to understand.

Teachers and others who evaluate the difficulty of textbooks may see implications for their work in this study.

(1) Teachers should be aware that textbooks and other materials that are written to conform to a readability formula may be harder to read than the formula results indicate. Writing otherwise difficult material with short sentences and easy words as measured by a formula does not necessarily improve readability. If textbook authors go beyond these formula factors in simplifying their writing, readability is more likely to be affected.

(2) This study does not show that readability formulas are invalid for other types of materials. If a teacher is sure that materials have not been manipulated artificially to affect readability formula results, the teacher may apply a formula to obtain a fairly accurate estimate of readability. The teacher should bear in mind, however, that formulas are more accurate for materials similar to those from which the formula was developed.

The present study suggests that the readability of textbook prose is not affected significantly by stylistic factors. Moreover, the study suggests that textbook writers and evaluators should not rely heavily on

readability formula results to determine textbook difficulty while overlooking powerful content effects. Finally, individual textbook samples may have idiosyncratic difficulties that need to be recognized and overcome.

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APPENDIX A

Dear

Thanks for agreeing to judge these materials and help me select the most appropriate for my experiment. I estimate it will take approximately two hours to read the passages and rate them. Try to read and evaluate them in a single sitting.

Procedures:

1. Read a passage, turn the page and rank the three listed factors according to how much each contributes, compared with the others, toward the difficulty of the passage.

2. After you have read and evaluated all of the passages, rank them below according to difficulty using your own subjective judgment. Put a one next to the easiest, a two next to the next easiest, etc. Please rank each passage without skipping any to facilitate computer analysis.

___ Anthropology: The Exploration of Human Diversity

___ Astronomy: The Evolving Universe (Chapter 1)

___ Astronomy: The Evolving Universe (Chapter 2)

___ Biology of Plants

___ Chemical Principles

___ Computers and the Cybernetic Society

___ Democracy Under Pressure: An Introduction to the American Political System

___ Principles of Macroeconomics

___ Speech: A Basic Text

3. Next rank the passages according to interest, again conforming to what seems interesting to you. Put a one next to the most interesting, a two next to second most interesting, etc. Again, please rank each passage without skipping any to facilitate computer analysis.

___ Anthropology: The Exploration of Human Diversity

___ Astronomy: The Evolving Universe (Chapter 1)

___ Astronomy: The Evolving Universe (Chapter 2)

___ Biology of Plants

___ Chemical Principles

___ Computers and the Cybernetic Society

___ Democracy Under Pressure: An Introduction to the American Political System

___ Principles of Macroeconomics

___ Speech: A Basic Text

INDIVIDUAL PASSAGE RATING SHEET

Hundreds of factors have been associated with passage difficulty. These three often appear in readability formulas. Decide which one seems most responsible for the difficulty of this passage and put a one next to it. Put a two next to the factor which seems next most responsible for the difficulty, etc.

_____sentence length

_____sentence structure

_____vocabulary

Definitions:

1. Sentence length--Sentences are long and connected by semi-colons and colons.

2. Sentence structure--Syntactic sentence structures are complicated or unfamiliar.

3. Vocabulary--Words are uncommon or unknown.

Although other factors may seem much more responsible for the difficulty than any of these three, please confine yourself to these and don't get too frustrated!

APPENDIX B

Identification Number_____

INSTRUCTIONS

Read the passage on the next page when you are told to start. Mark your ending time at the end of the passage. A 20-item short answer test will follow. Do not turn the page until you are told to begin.

from Computers and the Cybernetic Society (Chapter 1--Moving and Storing Information)

MOVING AND STORING INFORMATION

The Shape of a Computer System

A computer is a machine that can store a program and data, and then automatically execute the instructions with electronic speed. Thus, if the computer is to be of any use to us, there must be a way for us to feed programs and data into the computer, and a way for the computer to give us the results of its computation. The input device takes the user's data and instructions and transfers them to the memory of the computer. Whenever the computer has generated results, the output device transforms them into a form the user can understand or use in some other way.

At each stage, the information is carried in a different form. To get a feel for this, let us briefly examine a system more familiar to most readers: a tape recorder. A tape recorder is a system that can record sound on a magnetic tape, and can later play back whatever was recorded.

Consider the use of a tape recorder to record and play back a spoken message. The input device of a tape recorder is a microphone that converts the speech coming out of the person's mouth (which reaches the microphone as pressure waves in the air) into electrical signals. The output device is a loudspeaker that converts electrical signals into pressure waves in in the air which will enable the user to hear the original sound, or at least a slightly distorted reproduction of it.

The transforming of information from one form to another is called coding. Each form of the information is called a code. Thus the microphone

converts speech from the air-pressure code to the electrical signal code; and the loudspeaker works the other way. Speech can be stored on magnetic tape as a pattern of magnetization. (The details of this are not important. What is important is your own experience that speech--or other sounds, for that matter--can be recorded on magnetic tape, and that the code of the sound on the tape is neither pressure nor electric current.) During recording, the job of the tape control is to see that the electrical signals are converted into the appropriate pattern of magnetization on the magnetic tape. During playback, the job of the tape control is to convert the magnetization on the tape into the correct pattern of electrical signals which will make the loudspeaker recreate the recorded sound.

Sound is the medium of the main input to, and output from, a tape recorder. There is another kind of input: control signals like PLAY, RECORD, REWIND, FAST FORWARD, and STOP. These control signals enable the user to decide just what the machine will record, and what and when it will play back.

With the example of the tape recorder for comparison, we can now see how a computer is used in <u>interactive mode</u> in which the user gets results as soon as the computer generates them, and can type in new data and new instructions at any time.

The user interacts with the computer through a device called a <u>terminal</u>. The most common type of terminal looks much like an electric typewriter except for two differences: it has cables connecting it to the computer; and it is fed by a role of paper instead of sheets of paper.

When the user types away, he not only obtains the information typed on the paper, but he also has the typed symbols converted into electrical signals which are sent along the cable to the computer. When the terminal receives electrical signals from the computer, it will type out the corresponding

symbols on the paper in the terminal. Thus, these functions of the terminal are like the microphone and loudspeaker of the tape recorder.

What corresponds to the magnetic tape of the tape recorder? It is the memory, which is the region in the computer where data and programs are stored for automatic use by the machine. As data and instructions come into the computer as electrical signals, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form in the right place in the memory. As results are generated, the CPU must make sure that the proper electrical signals are sent to the terminal to make it type out the results for the user.

To this extent, the CPU is like the tape control of the tape recorder, but it does more. A computer does not simply store and retrieve information. It also follows the instructions of a program to process the information. It is the job of the CPU to take one instruction at a time out of memory. If it is an input instruction, the CPU will read information into the memory. If it is an output instruction, the CPU will send the appropriate information to the terminal. If it is an operation instruction, the CPU will retrieve the necessary data from memory, carry out the operation (adding two numbers together, for example), and--if appropriate--store the results at some designated place in memory. If the instruction calls for a test, the CPU will perform that test, and then go on to the instruction specified by the outcome of the test.

Finally we must see what sort of control signals the user can type in at the terminal. They are messages to the computer that are neither data nor part of a program. Instead, they tell the computer things like: "What I type in next will be data, so store it in such-and-such part of memory," or "What I type in next will be a program in FORTRAN, so use the proper translator when it is time to execute the program," or "I have

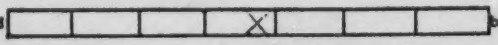
4

finished typing in my program and data; so start executing the program to process the data." Usually, the computer does not understand English, and so these control signals must actually be written in a special programming language called a job control language.

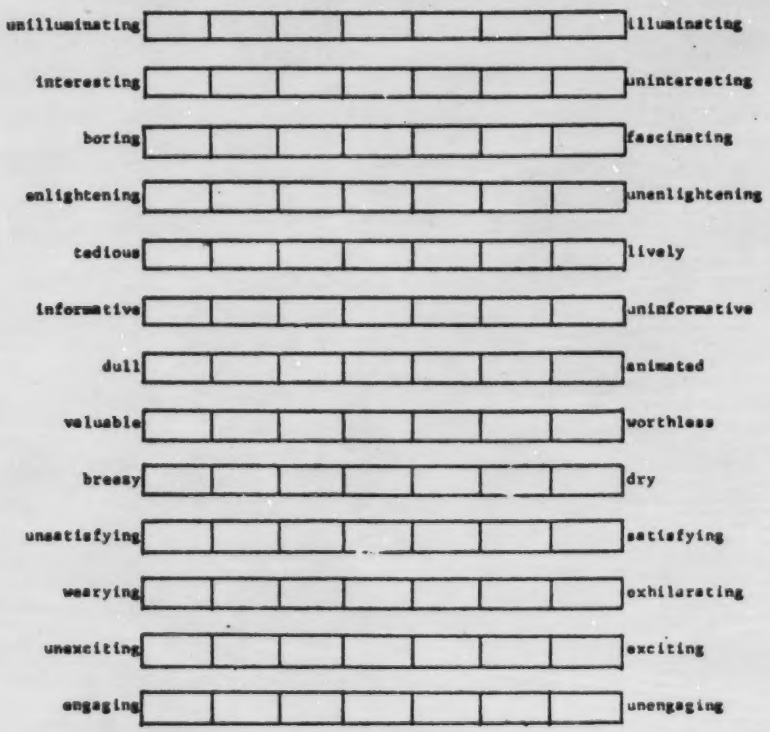
SURVEY

Before you take the comprehension test, please rate the passage on the following scales. For each item, place an X in the box that most nearly reflects your feeling about the passage.

Example:



Because the above person marked the center box, s/he felt the passage was neither good nor bad. If s/he had marked a box closer to the good, that would mean s/he felt the passage was more good than bad. If s/he had marked a box closer to the bad, that would mean s/he felt it was more bad than good. Rate how you feel about the passage on the following scales:



(Continue on next page)

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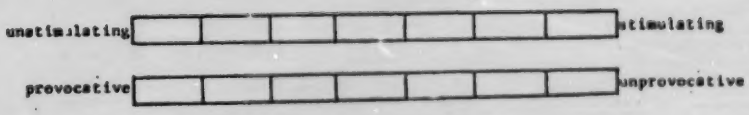

Now turn the page for the comprehension test.

APPENDIX C

ORIGINAL

A

Number_____Name_____School_____

ATTENTION: Record beginning time here:

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. The smallest living organisms are composed of single cells. The largest are made up of billions of cells, each of which still lives a partly independent existence. The realization that all organisms are composed of cells was one of the most important conceptual advances in the history of biology because it provided a unifying theme for the study of all living things. When studied at the cellular level, even the most diverse organisms are remarkably similar to one another, both in their physical organization and in their biochemical properties. The cell theory (which is, of course, not a theory at all but the observation of a fact) was formulated early in the nineteenth century, well before the presentation of Darwin's theory of evolution, but these

two great unifying concepts are, in fact, closely related. In the similarities among cells, we catch a glimpse of a long evolutionary history that links modern organisms, including plants and ourselves, with the first cellular units that took shape billions of years ago.

There are many, many different kinds of cells. Within our own bodies are more than 100 different and distinct cell types. In a teaspoon of pond water, you are likely to find several different kinds of one-celled organisms, and in a whole pond, there are probably several hundred clearly different kinds. Plants are composed of cells superficially quite different from those of our own body, and insects have many cells of kinds not found either in plants or in vertebrates. Thus, the first remarkable fact about cells is their diversity.

The second, even more remarkable fact is their similarity. Every cell is a self-contained and at least partially self-sufficient unit, bounded by an outer membrane, the plasma membrane or plasmalemma (often called simply the cell membrane), that controls the passage of materials in and out of the cell and so makes it possible for the cell to differ biochemically and structurally from its surroundings. As we shall see, this membrane has the same basic structure throughout the living world. Within this membrane is the cytoplasm which, in most cells, includes a variety of formed bodies as well as various dissolved and suspended molecules. Every cell also has at least one chromosome. In all types of cells, it is the DNA of the chromosome that encodes the genetic characteristics, and this genetic code is very much the same from bacterium to oak tree to man. (In evolutionary terms, this means

that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more striking. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy and to convert it from one form to another. The original source of energy for living systems on this planet is the sun. The chlorophyll-containing cells of green plants and of algae transform this radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms derive their energy by the oxidation of the products of photosynthesis. All life in this biosphere depends on the carefully controlled flow of energy from the sun through living cells back into the environment.

2. Cells use this energy to build and maintain their structure. Under the influence of the environment, an inanimate object--such as a mountain--will gradually fall apart, erode, and finally vanish. Living things, however, in the course of their interactions with the environment, not only are able to maintain themselves but also to grow and to evolve. (This relationship between energy and order is one of the most interesting principles of modern biology.)

3. In order to maintain and build more structure, the cell must take in substances ("building materials") from the outside. About 90 elements are found naturally on the earth's surface and in its atmosphere. Of these, living organisms utilize only 24, and 99 percent

of the bulk of living tissue is made up of 6 of these. Also, the elements that are used are often found within the cell in proportions very different from those in which they exist outside. In short, although cells constantly exchange materials with the environment, they maintain a relatively stable internal environment that is quite different from that of their surroundings.

4. Cells reproduce themselves, passing on to their daughter cells all the capacities that they themselves possess.

Prokaryotes vs. Eukaryotes

As we noted earlier, there are many different types of cells with striking diversities and similarities. Within these patterns of diversity and similarity, it is possible to identify two fundamentally distinct types of cellular organization: prokaryotic and eukaryotic. We shall examine prokaryotic cells here, because they are simpler and, in the evolutionary sense, more ancient.

The terms prokaryote and eukaryote are derived from the Greek word karyon, meaning "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus," and eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

The bacterium Escherichia coli is a good example of a modern prokaryote. These bacteria, which are very common, are inhabitants, usually harmless, of the human digestive tract. Because they are frequently used in modern studies of biochemistry and genetics, E coli may be the most thoroughly understood of all living systems.

E coli is quite simple in its general structure. Each consists of a cell wall, a plasma membrane, and the cytoplasm. The DNA, which is a single long molecule within the cytoplasm, contains the genetic information of the cell. In the bacterial cell, the DNA is in an extremely condensed form; if the molecule were fully extended, it would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells contain two molecules of DNA, and sometimes even four. This is because the DNA replicates before the cell divides and, in a fast-growing culture, DNA replication may get well ahead of cell division.

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minutes seconds

Please raise your hand so that this passage may be collected. You may begin working on the next page.

B

Number_____ Name_____ School_____

ATTENTION: Record beginning time here:

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. The smallest living organisms are made up of single cells. The largest are made up of billions of cells, each of which still lives a partly independent existence. The knowledge that all organisms are made of cells was one of the most important gains in understanding in the history of biology because it provided a unifying structure for the study of all living things. When studied at the cellular level, even the most differing organisms are surprisingly similar to one another, both in their physical organization and in their biochemical properties. The cell theory (which is, of course, not a theory at all but the recognition of a fact) was developed early in the nineteenth century, well before the presentation of Darwin's theory of evolution,

but these two great unifying ideas are, in fact, closely related. In the similarities among cells, we get an indication of the long evolutionary history that connects modern organisms, including plants and ourselves, with the first cellular units that formed billions of years ago.

There are many, many different kinds of cells. Within our own bodies are more than 100 different and distinct cell types. In a teaspoon of pond water, you are likely to find several different kinds of one-celled organisms, and in a whole pond, there are probably several hundred clearly different kinds. Plants are made of cells seemingly quite different from those of our own body, and insects have many cells of kinds not found either in plants or in vertebrates. Thus, the first notable fact about cells is their variety.

The second, even more striking fact is their similarity. Every cell is a self-contained and at least partly self-sufficient unit, held in by an outer membrane, the plasma membrane or plasmalemma (often called simply the cell membrane), that controls the passage of materials in and out of the cell and so makes it possible for the cell to differ biochemically and structurally from its surroundings. As we shall see, this membrane has the same basic structure throughout the living world. Within this membrane is the cytoplasm which, in most cells, includes a variety of formed bodies as well as various dissolved and suspended molecules. Every cell also has at least one chromosome. In all types of cells, it is the DNA of the chromosome that encodes the genetic characteristics, and this genetic code is very much the same

from bacterium to oak tree to man. (In evolutionary terms, this means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more apparent. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy and to change it from one form to another. The original producer of energy for living systems on Earth is the sun. The chlorophyll-containing cells of green plants and of algae change this radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms get their energy by the oxidation of the products of photosynthesis. All life in this biosphere is supported by the carefully controlled movement of energy from the sun through living cells back into the environment.

2. Cells use this energy to build and take care of their structure. Under the influence of the environment, an inanimate material--such as a mountain--will little by little fall apart, erode, and finally disappear. Living things, however, in the course of their involvement with the environment, not only are able to take care of themselves but also to grow and to evolve. (This relationship between energy and order is one of the most interesting principles of modern biology.)

3. In order to support and build more structure, the cell must take in resources ("building materials") from the outside. About 90

elements are found naturally on the earth's surface and in its atmosphere. Of these, living organisms use only 24, and 99 percent of the mass of living tissue is made up of 6 of these. Also, the elements that are used are often found within the cell in percentages very different from those in which they exist outside. In short, although cells continually trade materials with the environment, they keep a reasonably fixed inner environment that is quite different from that of their surroundings.

4. Cells reproduce themselves, passing on to their daughter cells all the qualities that they themselves have.

Prokaryotes vs. Eukaryotes

As we noted earlier, there are many different types of cells with obvious differences and similarities. Within these patterns of difference and similarity, it is possible to find two basically separate types of cellular organization: prokaryotic and eukaryotic. We shall look at prokaryotic cells here, because they are simpler and, in the evolutionary sense, older.

The terms prokaryote and eukaryote come from the Greek word karyon, meaning "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus," and eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

The bacterium Escherichia coli is a good example of a modern prokaryote. These bacteria, which are very common, are residents, usually safe, of the human digestive system. Because they are often

used in modern studies of biochemistry and genetics, E coli may be the most completely understood of all living systems.

E coli is quite simple in its general structure. Each is made up of a cell wall, a plasma membrane, and the cytoplasm. The DNA, which is a single long molecule within the cytoplasm, carries the genetic information of the cell. In the bacterial cell, the DNA is in a very compact form; if the molecule were fully extended, it would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells have two molecules of DNA, and sometimes even four. This is because the DNA replicates before the cell divides and, in a fast-growing culture, DNA replication may get well ahead of cell division.

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Please raise your hand so that this passage may be collected. You may begin working on the next page.

C

Number_____Name_____School_____

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. The smallest living organisms are composed of single cells. The largest are made up of billions of cells. Each cell of the largest organisms still lives a partly independent existence. The realization that all organisms are composed of cells was one of the most important conceptual advances in the history of biology. This is because it provided a unifying theme for the study of all living things. When studied at the cellular level, even the most diverse organisms are remarkably similar to one another. They are similar both in their physical organization and in their biochemical properties. The cell theory (which is, or course, not a theory at all but the observation of a fact) was formulated early in the nineteenth century. It was

formulated well before the presentation of Darwin's theory of evolution. But these two great unifying concepts are, in fact, closely related. In the similarities among cells, we catch a glimpse of a long evolutionary history. This evolutionary history links modern organisms, including plants and ourselves, with the first cellular units. These units took shape billions of years ago.

There are many, many different kinds of cells. Within our own bodies are more than 100 different and distinct cell types. In a teaspoon of pond water, you are likely to find several different kinds of one-celled organisms. In a whole pond, there are probably several hundred clearly different kinds. Plants are composed of cells superficially quite different from those of our own body. Insects have many cells of kinds not found either in plants or in vertebrates. Thus, the first remarkable fact about cells is their diversity.

The second, even more remarkable fact is their similarity. Every cell is a self-contained and at least partially self-sufficient unit. Furthermore, every cell is bounded by an outer membrane. This is the plasma membrane or plasmalemma (often called simply the cell membrane). The outer membrane controls the passage of materials in and out of the cell. Thus, the outer membrane makes it possible for the cell to differ biochemically and structurally from its surroundings. The membrane has the same basic structure throughout the living world. Within the membrane is the cytoplasm. The cytoplasm in most cells includes a variety of formed bodies. It also includes various dissolved and suspended molecules. Every cell also has at least one

chromosome. In all types of cells, it is the DNA of the chromosome that encodes the genetic characteristics. The genetic code is very much the same from bacterium to oak tree to man. (In evolutionary terms, this means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more striking. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy. They also can convert it from one form to another. The original source of energy for living systems on this planet is the sun. The chlorophyll-containing cells of green plants and of algae transform this radiant energy to chemical energy. They do this by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms derive their energy by the oxidation of the products of photosynthesis. All life in this biosphere depends on a carefully controlled flow of energy. The energy flows from the sun through living cells back into the environment.

2. Cells use this energy to build and maintain their structure. Under the influence of the environment, an inanimate object--such as a mountain--will gradually fall apart, erode, and finally vanish. Living things, however, in the course of their interactions with the environment, are able to maintain themselves. They are also able to grow and to evolve. (This relationship between energy and order is one of the most interesting principles of modern biology.)

3. In order to maintain and build more structure, the cell must take in substances ("building materials") from the outside. About 90 elements are found naturally on the earth's surface and in its atmosphere. Of these, living organisms utilize only 24. Moreover, 99 percent of the bulk of living tissue is made up of 6 of these. Also, the elements that are used are often found within the cell in proportions very different from those in which they exist outside. In short, cells constantly exchange materials with the environment. Even so, they maintain a relatively stable internal environment. This environment is quite different from that of their surroundings.

4. Cells reproduce themselves. They pass on to their daughter cells all the capacities that they themselves possess.

Prokaryotes vs. Eukaryotes

As we noted earlier, there are many different types of cells. We noted that these have striking diversities and similarities. Within these patterns of diversity and similarity, it is possible to identify two fundamentally distinct types of cellular organization. These are prokaryotic and eukaryotic. We shall examine prokaryotic cells here. This is because they are simpler and, in the evolutionary sense, more ancient.

The terms prokaryote and eukaryote are derived from the Greek word karyon. Karyon means "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus." Eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

The bacterium Escherichia coli is a good example of a modern prokaryote. These bacteria are very common. They are inhabitants, usually harmless, of the human digestive tract. E coli are frequently used in modern studies of biochemistry and genetics. For this reason they may be the most thoroughly understood of all living systems.

E coli is quite simple in its general structure. Each consists of a cell wall, a plasma membrane, and the cytoplasm. The DNA is a single long molecule within the cytoplasm. It contains the genetic information of the cell. In the bacterial cell, the DNA is in an extremely condensed form. If the molecule were fully extended, it would be about 700 times longer than the entire cell. It is also in the form of a circle. That is, there are no ends to the molecule.

Often E coli cells contain two molecules of DNA. Sometimes they even contain four. This is because the DNA replicates before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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SENTENCE STRUCTURE

D

Number_____Name_____School_____

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. Living organisms are composed of cells--the smallest organisms composed of single cells, the largest made up of billions of cells still living a partly independent existence. The realization that all organisms are composed of cells provides a unifying theme for the study of all living things, resulting in one of the most important conceptual advances in the history of biology. When studied at the cellular level, organisms are similar; even the most diverse organisms are remarkably similar to one another, similar in their physical organization, similar in their biochemical properties. The cell theory is a great unifying concept, though it is not a theory at all, of course, but the observation of a

fact. It was formulated early in the nineteenth century, well before the presentation of Darwin's theory of evolution which is another great unifying concept. But both concepts are, in fact, closely related. In the similarities among cells we catch a glimpse of history, a long evolutionary history, which links modern organisms, including plants and ourselves, with the first cellular units that took shape billions of years ago.

There are many, many different kinds of cells. Our own bodies contain cells of more than 100 different and distinct types. Pond water contains different kinds of one-celled organisms--several different kinds in a teaspoon of pond water and several hundred clearly different kinds in a whole pond. Cells differ among organisms--plants having cells superficially quite different from those of our own body, insects having cells of kinds not found either in plants or in vertebrates. Thus, the first remarkable fact about cells is their diversity.

The second, even more remarkable fact is their similarity. Every cell is a unit, self-contained and at least partially self-sufficient, bounded by an outer membrane, the plasma membrane or plasmalemma (often called simply the cell membrane). The outer membrane controls the passage of materials in and out of the cell, making it possible for the cell to differ from its surroundings--differ biochemically and structurally. As we shall see, the outer membrane has the same basic structure throughout the living world. Within this membrane is the cytoplasm which, in most cells, includes various formed bodies as well

as dissolved or suspended molecules. Every type of cell also has at least one chromosome whose DNA encodes the genetic characteristics, a genetic code which is very much the same from bacterium to oak tree to man. (In evolutionary terms, this similarity means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more striking. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy and to convert it from one form to another. For living systems on this planet, the original source of energy is the sun. The sun's energy is transformed by certain cells--the chlorophyll-containing cells of green plants and of algae, that transform radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells, such as those of plants, animals and other organisms, derive their energy by the oxidation of the products of photosynthesis. In this biosphere, all life depends on energy, on the carefully controlled flow of energy--passing from the sun, moving through living cells, going back into the environment.

2. Cells use this energy to build and maintain their structure. Under the influence of the environment, an inanimate object will gradually fall apart; a mountain, for example, will erode and finally vanish. Living things, however, not only are able to maintain themselves, but also to grow and evolve in the course of their

interactions with the environment. (This relationship between energy and order is one of the most interesting principles of modern biology).

3. In order to maintain and build more structure, the cell must take in outside substances or "building materials," elements found naturally on the earth's surface and in its atmosphere. Out of about 90 elements, living organisms utilize only 24, six elements making up 99 percent of the bulk of living tissue. Also, within the cell, elements are often found in proportions very different from those in which they exist outside. In short, although cells constantly exchange materials with their surroundings, they maintain a relatively stable internal environment, an environment that is quite different from that of their surroundings.

4. Cells reproduce themselves, passing on to their daughter cells all the capacities that they themselves possess.

Prokaryotes vs. Eukaryotes

As we noted earlier, cells are of many different types, with striking diversities and similarities. Within these patterns of diversity and similarity, it is possible to identify two types of cellular organizations, prokaryotic and eukaryotic, cellular organizations that are fundamentally distinct from each other. We shall examine prokaryotic cells here, because they are simpler and more ancient, ancient in the evolutionary sense.

The terms prokaryote and eukaryote are derived from the Greek word karyon, meaning "nut" or "kernel (nucleus)," prokaryotes meaning

"before the nucleus" and eukaryotes meaning "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

A good example of a modern prokaryote is the Escherichia coli, a very common and usually harmless bacterium inhabiting the human digestive tract. Of all living systems, E coli may be the most thoroughly understood, resulting from its frequent use in modern studies of biochemistry and genetics.

E coli is quite simple in its general structure, each bacterium consisting of a cell wall, a plasma membrane, and the cytoplasm. Within the cytoplasm is the DNA, a single long molecule containing the genetic information of the cell. In the bacterial cell, the DNA is in an extremely condensed form; fully extended, the molecule would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells contain two molecules of DNA, sometimes even four, resulting from the DNA replicating before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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Please raise your hand so that this passage may be collected. You may begin working on the next page.

E

Number_____Name_____School_____

ATTENTION: Record beginning time here:

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. The smallest living organisms are made of single cells. The largest are made up of billions of cells. Each cell of the largest organisms still lives a partly independent existence. The knowledge that all organisms are made of cells was one of the most important gains in understanding in the history of biology. This is because it provided a unifying structure for the study of all living things. When studied at the cellular level, even the most differing organisms are notably similar to one another. They are similar both in their physical organization and in their biochemical properties. The cell theory (which is, of course, not a theory at all but the recognition of a fact) was

developed early in the nineteenth century. It was developed well before the presentation of Darwin's theory of evolution. But these two great unifying ideas are, in fact, closely related. In the similarities among cells, we get an indication of a long evolutionary history. This evolutionary history connects modern organisms, including plants and ourselves, with the first cellular units. These units formed billions of years ago.

There are many, many different kinds of cells. Within our own bodies are more than 100 different and distinct cell types. In a teaspoon of pond water, you are likely to find several different kinds of one-celled organisms. In a whole pond, there are probably several hundred clearly different kinds. Plants are made of cells seemingly quite different from those of our own body. Insects have many cells of kinds not found either in plants or in vertebrates. Thus, the first notable fact about cells is their variety.

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suspended molecules. Every cell also has at least one chromosome. In all types of cells, it is the DNA of the chromosome that encodes the genetic characteristics. The genetic code is very much the same from bacterium to oak tree to man. (In evolutionary terms, this means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more apparent. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy. They also can change it from one form to another. The original producer of energy for living systems on Earth is the sun. The chlorophyll-containing cells of green plants and of algae change this radiant energy to chemical energy. They do this by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms get their energy by the oxidation of the products of photosynthesis. All life in this biosphere is supported by a carefully controlled movement of energy. The energy moves from the sun through living cells back into the environment.

2. Cells use this energy to build and take care of their structure. Under the influence of the environment, inanimate material--such as a mountain--will little by little fall apart, erode, and finally disappear. Living things, however, in the course of their involvement with the environment, are able to take care of themselves. They are also able to grow and to evolve. (This relationship between

energy and order is one of the most interesting principles of modern biology.)

3. In order to support and build more structure, the cell must take in resources ("building materials") from the outside. About 90 elements are found naturally on the earth's surface and in its atmosphere. Of these, living organisms use only 24. Moreover, 99 percent of the mass of living tissue is made up of 6 of these. Also, the elements that are used are often found within the cell in percentages very different from those in which they exist outside. In short, cells constantly trade materials with the environment. Even so, they keep a reasonably fixed inner environment. This environment is quite different from that of their surroundings.

4. Cells reproduce themselves. They pass on to their daughter cells all the qualities that they themselves have.

P

Prokaryotes vs. Eukaryotes

As we noted earlier, there are many different types of cells. We noted that these have obvious differences and similarities. Within these patterns of difference and similarity, it is possible to find two basically separate types of cellular organization. These are prokaryotic and eukaryotic. We shall look at prokaryotic cells here. This is because they are simpler and, in the evolutionary sense, older.

The terms prokaryote and eukaryote come from the Greek word karyon. Karyon means "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus." Eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

The bacterium Escherichia coli is a good example of a modern prokaryote. These bacteria are very common. They are residents, usually safe, of the human digestive system. E coli are often used in modern studies of biochemistry and genetics. For this reason they may be the most completely understood of all living systems.

E coli is quite simple in its general structure. Each is made of a cell wall, a plasma membrane, and the cytoplasm. The DNA is a single long molecule within the cytoplasm. It carries the genetic information of the cell. In the bacterial cell, the DNA is in a very compact form. If the molecule were fully extended, it would be about 700 times longer than the entire cell. It is also in the form of a circle. That is, there are no ends to the molecule.

Often E coli cells have two molecules of DNA. Sometimes they even have four. This is because the DNA replicates before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. Living organisms are made of cells--the smallest organisms made of single cells, the largest made up of billions of cells still living a partly independent existence. The knowledge that all organisms are made of cells provides a unifying structure for the study of all living things, resulting in one of the most important gains in understanding in the history of biology. When studied at the cellular level, organisms are similar; even the most differing organisms are surprisingly similar to one another, similar in their physical organization, similar in their biochemical properties. The cell theory is a great unifying idea, though it is not a theory at all, of course, but the recognition of a fact. It was developed early in the nineteenth century, well before

the presentation of Darwin's theory of evolution which is another great unifying idea. But both ideas are, in fact, closely related. In the similarities among cells we get an indication of history, a long evolutionary history, which connects modern organisms, including plants and ourselves, with the first cellular units that formed billions of years ago.

There are many, many different kinds of cells. Our own bodies have cells of more than 100 different and distinct types. Pond water has different kinds of one-celled organisms--several different kinds in a teaspoon of pond water and several hundred clearly different kinds in a whole pond. Cells differ among organisms--plants having cells seemingly quite different from those of our own body, insects having cells of kinds not found either in plants or in vertebrates. Thus, the first notable fact about cells is their variety.

The second, even more striking fact is their similarity. Every cell is a unit, self-contained and at least partly self-sufficient, held in by an outer membrane, the plasma membrane or plasmalemma (often called simply the cell membrane). The outer membrane controls the passage of materials in and out of the cell, making it possible for the cell to differ from its surroundings--differ biochemically and structurally. As we shall see, the outer membrane has the same basic structure throughout the living world. Within this membrane is the cytoplasm which, in most cells, includes various formed bodies as well as dissolved or suspended molecules. Every type of cell also has at least one chromosome whose DNA encodes the genetic characteristics, a genetic code which is very much the same from bacterium to oak tree to

man. (In evolutionary terms, this similarity means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more apparent. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy and to change it from one form to another. For living systems on this planet, the original producer of energy is the sun. The sun's energy is changed by certain cells--the chlorophyll-containing cells of green plants and of algae, that change radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells, such as those of plants, animals and other organisms, get their energy by the oxidation of the products of photosynthesis. In this biosphere, all life is supported by energy, by the carefully controlled flow of energy--passing from the sun, moving through living cells, going back into the environment.

2. Cells use this energy to build and take care of their structure. Under the influence of the environment, inanimate objects will little by little fall apart; a mountain, for example, will erode and finally disappear. Living things, however, not only are able to take care of themselves, but also to grow and evolve in the course of their involvement with the environment. (This relationship between energy and order is one of the most interesting principles of modern biology).

3. In order to support and build more structure, the cell must take in outside resources or "building materials," elements found

naturally on the earth's surface and in its atmosphere. Out of about 90 elements, living organisms use only 24, six elements making up 99 percent of the mass of living tissue. Also, within the cell, elements are often found in percentages very different from those in which they exist outside. In short, although cells continually trade materials with the environment, they keep a reasonably fixed inner environment, an environment that is quite different from that of their surroundings.

4. Cells reproduce themselves, passing on to their daughter cells all the qualities that they themselves have.

Prokaryotes vs. Eukaryotes

As we noted earlier, cells are of many different types, with obvious differences and similarities. Within these patterns of difference and similarity, it is possible to find two types of cellular organizations, prokaryotic and eukaryotic, cellular organizations that are basically separate from each other. We shall look at prokaryotic cells here, because they are simpler and older, older in the evolutionary sense.

The terms prokaryote and eukaryote come from the Greek word karyon, meaning "nut" or "kernel (nucleus)," prokaryotes meaning "before the nucleus" and eukaryotes meaning "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

A good example of a modern prokaryote is the Escherichia coli, a very common and usually safe bacterium living in the human digestive system. Of all living systems, E coli may be the most completely understood, resulting from its use often in modern studies of biochemistry and genetics.

E coli is quite simple in its general structure, each bacterium being made of a cell wall, a plasma membrane, and the cytoplasm. Within the cytoplasm is the DNA, a single long molecule carrying the genetic information of the cell. In the bacterial cell, the DNA is in a very compact form; fully extended, the molecule would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells have two molecules of DNA, sometimes even four, resulting from the DNA replicating before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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Number_____Name_____School_____

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from Biology of Plants

INTRODUCTION TO THE CELL

Cells are the structural and functional units of life. Living organisms are composed of cells. The smallest organisms are composed of single cells. The largest organisms are made up of billions of cells still living a partly independent existence. The realization that all organisms are composed of cells provides a unifying theme for the study of all living things. Because it provides such a unifying theme, this realization is one of the most important conceptual advances in the history of biology. When studied at the cellular level, organisms are similar. Even the most diverse organisms are remarkably similar to one another, similar in their physical organization, similar in their biochemical properties. The cell theory is a great unifying concept, though it is not a theory at all, of

course, but the observation of a fact. It was formulated early in the nineteenth century, well before the presentation of another great unifying concept--Darwin's theory of evolution. But both concepts are, in fact, closely related. In the similarities among cells we catch a glimpse of history. This long evolutionary history links modern organisms, including plants and ourselves, with the first cellular units that took shape billions of years ago.

There are many, many different kinds of cells. Our own bodies contain cells of more than 100 different and distinct types. Pond water contains different kinds of one-celled organisms. Several different kinds of such organisms are in a teaspoon of pond water. Several hundred clearly different kinds are in a whole pond. Cells differ among organisms. Plants have cells superficially quite different from those of our own body. Insects have cells of kinds not found either in plants or in vertebrates. Thus, the first remarkable fact about cells is their diversity.

The second, even more remarkable fact is their similarity. Every cell is a unit, self-contained and at least partially self-sufficient. The cell is bounded by an outer membrane, the plasma membrane or plasmalemma (often called simply the cell membrane). The outer membrane controls the passage of materials in and out of the cell, making it possible for the cell to differ from its surroundings--differ biochemically and structurally. As we shall see, the outer membrane has the same basic structure throughout the living world. Within this membrane is the cytoplasm. In most cells, the cytoplasm includes various formed bodies as well as dissolved or suspended molecules.

Every type of cell also has at least one chromosome whose DNA encodes genetic characteristics. This genetic code is very much the same from bacterium to oak tree to man. (In evolutionary terms, the similarity among genetic codes means that the genetic code was probably in existence in its present form more than 3 billion years ago.)

Considered functionally, the similarities among cells are even more striking. Let us look at the four most important functions of cells.

1. Cells have the ability to take in energy. Moreover, they can convert it from one form to another. For living systems on this planet, the original source of energy is the sun. The sun's energy is transformed by certain cells. These are the chlorophyll-containing cells of green plants and of algae. Such cells transform radiant energy to chemical energy by the process of photosynthesis. Nonphotosynthetic cells may be present in plants, animals and other organisms. These cells derive their energy by the oxidation of the products of photosynthesis. In this biosphere, all life depends on energy, on the carefully controlled flow of energy--passing from the sun, moving through living cells, going back into the environment.

2. Cells use this energy to build and maintain their structure. Under the influence of the environment, inanimate objects will gradually fall apart. A mountain, for example, will erode and finally vanish. Living things, however, are able to maintain themselves. Furthermore, they are able to grow and evolve in the course of their interactions with the environment. (This relationship between energy and order is one of the most interesting principles of modern biology).

3. In order to maintain and build more structure, the cell must take in outside substances or "building materials." These elements are found naturally on the earth's surface and in its atmosphere. Out of about 90 elements, living organisms utilize only 24. Of these 24 elements, 6 make up 99 percent of the bulk of living tissue. Also, within the cell, elements are often found in proportions very different from those in which they exist outside. In short, cells constantly exchange materials with the environment. Even so, they maintain a relatively stable internal environment. This internal environment is quite different from that of their surroundings.

4. Cells reproduce themselves. They pass on to their daughter cells all the capacities that they themselves possess.

Prokaryotes vs. Eukaryotes

As we noted earlier, cells are of many different types, with striking diversities and similarities. Within these patterns of diversity and similarity, it is possible to identify two types of cellular organizations, prokaryotic and eukaryotic. These cellular organizations are fundamentally distinct from each other. We shall examine prokaryotic cells here, because they are simpler and more ancient, ancient in the evolutionary sense.

The terms prokaryote and eukaryote are derived from the Greek word karyon, meaning "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus," and eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

A good example of a modern prokaryote is the Escherichia coli. It is a very common and usually harmless bacterium which inhabits the human digestive tract. Of all living systems, E coli may be the most thoroughly understood. This is because they are frequently used in modern studies of biochemistry and genetics.

E coli is quite simple in its general structure. Each bacterium consists of a cell wall, a plasma membrane, and the cytoplasm. Within the cytoplasm is the DNA, a single long molecule containing the genetic information of the cell. In the bacterial cell, the DNA is in an extremely condensed form. Fully extended, the molecule would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells contain two molecules of DNA. Sometimes they even contain four molecules, resulting from the DNA replicating before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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from Biology of Plants

INTRODUCTION TO THE CELL

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of a fact. It was developed early in the nineteenth century, well before the presentation of another great unifying idea--Darwin's theory of evolution. But both ideas are, in fact, closely related. In the similarities among cells we get an indication of evolutionary history. This history connects modern organisms, including plants and ourselves, with the first cellular units that formed billions of years ago.

There are many, many different kinds of cells. Our own bodies have cells of more than 100 different and distinct types. Pond water has different kinds of one-celled organisms. Several different kinds of such organisms are in a teaspoon of pond water. Several hundred clearly different kinds are in a whole pond. Cells differ among organisms. Plants have cells seemingly quite different from those of our own body. Insects have cells of kinds not found either in plants or in vertebrates. Thus, the first notable fact about cells is their variety.

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1. Cells have the ability to take in energy. Moreover, they can change it from one form to another. For living systems on Earth, the original producer of energy is the sun. The sun's energy is changed by certain cells. These are the chlorophyll-containing cells of green plants and of algae. Such cells change radiant energy to chemical energy by the process of photosynthesis. Nonphotosynthetic cells may be present in plants, animals and other organisms. These cells get their energy by the oxidation of the products of photosynthesis. In this biosphere, all life is supported by energy, by the carefully controlled movement of energy--passing from the sun, moving through living cells, going back into the environment.

2. Cells use this energy to build and take care of their structure. Under the influence of the environment, inanimate material will little by little fall apart. A mountain, for example, will erode and finally disappear. Living things, however, are able to take care of themselves. Furthermore, they are able to grow and evolve in the course of their involvement with the environment. (This relationship between energy and order is one of the most interesting principles of modern biology).

3. In order to support and build more structure, the cell must take in outside resources or "building materials." These elements are found naturally on the earth's surface and in its atmosphere. Out of about 90 elements, living organisms use only 24. Of these 24 elements, 6 make up 99 percent of the mass of living tissue. Also, within the cell, elements are often found in percentages very different from those in which they exist outside. In short, cells continually trade materials with the environment. Even so, they keep a reasonably fixed inner environment. This inner environment is quite different from that of their surroundings.

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Prokaryotes vs. Eukaryotes

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The terms prokaryote and eukaryote come from the Greek word karyon, meaning "nut" or "kernel (nucleus)." Prokaryotes are "before the nucleus," and eukaryotes are "with a true nucleus." Modern prokaryotes include the bacteria and the blue-green algae.

Prokaryotic Cells

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E coli is quite simple in its general structure. Each bacterium is made of a cell wall, a plasma membrane, and the cytoplasm. Within the cytoplasm is the DNA, a single long molecule carrying the genetic information of the cell. In the bacterial cell, the DNA is in a very compact form. Fully extended, the molecule would be about 700 times longer than the entire cell. It is also in the form of a circle--that is, there are no ends to the molecule.

Often E coli cells have two molecules of DNA. Sometimes they even have four molecules, resulting from the DNA replicating before the cell divides. In a fast-growing culture, DNA replication may get well ahead of cell division.

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APPENDIX D

ORIGINAL

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from Computers and the Cybernetic Society

MOVING AND STORING INFORMATION

The Shape of a Computer System

A computer is a machine that can store instructions and data, and then automatically execute the instructions with electronic speed. Thus, if the computer is to be of any use to us, there must be a way for us to feed instructions and data into the computer, and a way for the computer to give us the results of its computation. The imput device takes the user's data and instructions and transfers them to the memory of the computer. Whenever the computer has generated results, the output device transforms them into a form the user can understand or use in some other way.

At each stage, the information is carried in a different form. To get a feel for this, let us briefly examine a system more familiar to

most readers: a tape recorder. A tape recorder is a system that can record sound on a magnetic tape, and can later play back whatever was recorded.

Consider the use of a tape recorder to record and play back a spoken message. The input device of a tape recorder is a microphone that converts the speech coming out of the person's mouth (which reaches the microphone as pressure waves in the air) into electrical signals. The output device is a loudspeaker that converts electrical signals into pressure waves in the air which will enable the user to hear the original sound, or at least a slightly distorted reproduction of it.

The transforming of information from one form to another is called coding. Each form of the information is called a code. Thus the microphone converts speech from the air-pressure code to the electrical signal code; and the loudspeaker works the other way. Speech can be stored on magnetic tape as a pattern of magnetization. (The details of this are not important. What is important is your own experience that speech--or other sounds, for that matter--can be recorded on magnetic tape, and that the code of the sound on the tape is neither pressure nor electric current.) During recording, the job of the tape control is to see that the electrical signals are converted into the appropriate pattern of magnetization on the magnetic tape. During playback, the job of the tape control is to convert the magnetization on the tape into the correct pattern of electrical signals which will make the loudspeaker recreate the recorded sound.

Sound is the medium of the main input to, and output from, a tape recorder. There is another kind of input: control signals like PLAY, RECORD, REWIND, FAST FORWARD, and STOP. These control signals enable the user to decide just what the machine will record, and what and when it will play back.

With the example of the tape recorder for comparison, we can now see how a computer is used in interactive mode in which the user gets results as soon as the computer generates them, and can type in new data and new instructions at any time.

The user interacts with the computer through a device called a terminal. The most common type of terminal looks much like an electric typewriter except for two differences: it has cables connecting it to the computer; and it is fed by a role of paper instead of sheets of paper.

When the user types away, he not only obtains the information typed on the paper, but he also has the typed symbols converted into electrical signals which are sent along the cable to the computer. When the terminal receives electrical signals from the computer, it will type out the corresponding symbols on the paper in the terminal. Thus, these functions of the terminal are like the microphone and loudspeaker of the tape recorder.

What corresponds to the magnetic tape of the tape recorder? It is the memory, which is the region in the computer where data and programs are stored for automatic use by the machine. As data and instructions come into the computer as electrical signals, the central processing unit (CPU, for short) must make sure that the information is stored in

properly coded form in the right place in the memory. As results are generated, the CPU must make sure that the proper electrical signals are sent to the terminal to make it type out the results for the user.

To this extent, the CPU is like the tape control of the tape recorder, but it does more. A computer does not simply store and retrieve information. It also follows the instructions of a program to process the information. It is the job of the CPU to take one instruction at a time out of memory. If it is an input instruction, the CPU will read information into the memory. If it is an output instruction, the CPU will send the appropriate information to the terminal. If it is an operation instruction, the CPU will retrieve the necessary data from memory, carry out the operation (adding two numbers together, for example), and --if appropriate--store the results at some designated place in memory. If the instruction calls for a test, the CPU will perform that test, and then go on to the instruction specified by the outcome of the test.

Finally we must see what sort of control signals the user can type in at the terminal. They are messages to the computer that are neither data nor part of a program. Instead, they tell the computer things like: "What I type in next will be data, so store it in such-and-such part of memory," or "What I type in next will be a program in FORTRAN, so use the proper translator when it is time to execute the program," or "I have finished typing in my program and data; so start executing the program to process the data." Usually, the computer does not understand English, and so these control signals must actually be

written in a special programming language called a job control language.

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WORD FREQUENCY

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from Computers and the Cybernetic Society

MOVING AND STORING INFORMATION

The Shape of a Computer System

A computer is a machine that can store instructions and data, and then by itself execute the instructions at electronic rates. Thus, if the computer is to be of any use to us, there must be a way for us to feed instructions and data into the computer, and a way for the computer to give us the results of its calculation. The imput device takes the user's data and instructions and moves them to the memory of the computer. When the computer has produced results, the output device changes them into a form the user can understand or use in some other way.

At each stage, the information is carried in a different form. To get a feel for this, let us look for a moment at a system more known to

most readers: a tape recorder. A tape recorder is a system that can record sound on a magnetic tape, and can later play back whatever was recorded.

Consider the use of a tape recorder to record and play back a spoken communication. The input device of a tape recorder is a microphone that changes the words coming out of the person's mouth (which reaches the microphone as pressure waves in the air) into electrical signals. The output device is a loudspeaker that changes electrical signals into pressure waves in the air which will let the user hear the original sound, or at least a somewhat changed copy of it.

The changing of information from one form to another is called coding. Each form of the information is called a code. Thus the microphone changes words from the air-pressure code to the electrical signal code; and the loudspeaker works the other way. Words can be stored on magnetic tape as a pattern of magnetization. (The particulars of this are not important. What is important is your own experience that words--or other sounds, for that matter--can be recorded on magnetic tape, and that the code of the sound on the tape is neither pressure nor electric current.) During recording, the job of the tape control is to see that the electrical signals are changed into the right pattern of magnetization on the magnetic tape. During playback, the job of the tape control is to change the magnetization on the tape into the right pattern of electrical signals which will make the loudspeaker produce again the recorded sound.

Sound is the medium of the main input to, and output from, a tape recorder. There is another kind of input: control signals like PLAY, RECORD, REWIND, FAST FORWARD, and STOP. These control signals let the user decide just what the machine will record, and what and when it will play back.

With the example of the tape recorder for contrast, we can now see how a computer is used in interactive mode in which the user gets results as soon as the computer produces them, and can type in new data and new instructions at any time.

The user interacts with the computer through a device called a terminal. The most common type of terminal looks much like an electric typewriter except for two differences: it has wires joining it to the computer; and it is fed by a role of paper instead of pieces of paper.

When the user types away, he not only obtains the information typed on the paper, but he also has the typed symbols changed into electrical signals which are sent along the wire to the computer. When the terminal receives electrical signals from the computer, it will type out the matching symbols on the paper in the terminal. Thus, these functions of the terminal are like the microphone and loudspeaker of the tape recorder.

What is like the magnetic tape of the tape recorder? It is the memory, which is the part of the computer where data and programs are stored for automatic use by the machine. As data and instructions come into the computer as electrical signals, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form in the right place in the memory. As results are

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Finally we must see what sort of control signals the user can type in at the terminal. They are communications to the computer that are neither data nor part of a program. Instead, they tell the computer things like: "What I type in next will be data, so store it in such-and-such part of memory," or "What I type in next will be a program in FORTRAN, so use the right translator when it is time to execute the program," or "I have stopped typing in my program and data; so start executing the program to process the data." Usually, the computer does not understand English, and so these control signals must actually be written in a special programming language called a job control language.

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Number_____ Name_____ School_____

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from Computers and the Cybernetic Society

MOVING and STORING INFORMATION

The Shape of a Computer System

A computer is a machine that can store instructions and data. It can then automatically execute the instructions with electronic speed. Thus, if the computer is to be of any use to us, there must be a way for us to feed programs and data into the computer. Also, there must be a way for the computer to give us the results of its computation. The input device takes the user's data and instructions. Then it transfers them to the memory of the computer. Whenever the computer has generated results, the output device transforms them. It transforms them into a form the user can understand or use in some other way.

At each stage, the information is carried in a different form. To get a feel for this, let us briefly examine a system more familiar to most readers: a tape recorder. A tape recorder is a system that can record sound on a magnetic tape. Later it can play back whatever was recorded.

Consider the use of a tape recorder to record and play back a spoken message. The input device of a tape recorder is a microphone. The microphone converts the speech coming out of the person's mouth. The speech reaches the microphone as pressure waves in the air. The microphone converts the speech into electrical signals. The output device is a loudspeaker. The loudspeaker converts electrical signals into pressure waves in the air. This will enable the user to hear the original sound, or at least a slightly distorted reproduction of it.

The transforming of information from one form to another is called coding. Each form of the information is called a code. Thus the microphone converts speech from the air-pressure code to the electrical signal code. The loudspeaker works the other way. Speech can be stored on magnetic tape as a pattern of magnetization. (The details of this are not important. What is important is your own experience that speech--or other sounds, for that matter--can be recorded on magnetic tape. Also important is that the code of the sound on the tape is neither pressure nor electric current.) During recording, the job of the tape control is to see that the electrical signals are converted. These signals are converted into the appropriate pattern of magnetization. During playback, the job of the tape control is to convert the magnetization on the tape. It converts the magnetization

into the correct pattern of electrical signals. These signals will make the loudspeaker recreate the recorded sound.

Sound is the medium of the main input to a tape recorder. It is also the medium of the main output from a tape recorder. There is another kind of input: control signals like PLAY, RECORD, REWIND, FAST FORWARD, and STOP. These control signals enable the user to decide just what the machine will record. The signals also enable the user to decide what and when it will play back.

With the example of the tape recorder for comparison, we can now see how a computer is used in interactive mode. When a computer is in interactive mode, the user gets results as soon as the computer generates them. Furthermore, the user can type in new data and new instructions at any time.

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SENTENCE STRUCTURE

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from Computers and the Cybernetic Society

MOVING AND STORING INFORMATION

The Shape of a Computer System

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MOVING and STORING INFORMATION

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MOVING AND STORING INFORMATION

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MOVING AND STORING INFORMATION

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APPENDIX E

Words Substituted in the Cells Passages

Original		Substitution	
WORD	FREQUENCY	WORD	FREQUENCY
composed	40	made up of	1125
realization	69	knowledge	145
composed	40	made of	1125
conceptual	85	understanding	137
advances	60	gains	74
theme	55	structure	91
diverse	13	differing	312
remarkably	47	surprisingly	58
observation	73	recognition	80
formulated	17	developed	170
concepts	85	ideas	195
catch	43	get	750
glimpse	16	indication	80
links	7	connects	33
took shape	85	formed	370
composed	40	made of	1125
superficially	7	seemingly	229
remarkable	47	notable	127
diversity	13	variety	201
remarkable	47	striking	50
partially	25	partly	49
bounded	42	held in	60
striking	50	apparent	125
convert	20	change	240
source	88	producer	90
planet	22	Earth	150
transform	25	change	240
derive	39	get	750
depends on	49	is supported by	180
flow	67	movement	128
maintain	60	take care of	162
gradually	51	little by little	831

vanish	15	disappear	35
interactions	17	involvement	147
maintain	60	take care of	162
maintain	60	support	180
substances	33	resources	72
utilize	10	use	589
bulk	16	mass	110
proportions	29	percentages	45
constantly	71	continually	133
exchange	70	trade	143
maintain	60	keep	264
relatively	85	reasonably	241
stable	30	fixed	87
internal	55	inner	62
capacities	5	qualities	114
striking	39	obvious	92
diversities	13	differences	148
diversity	13	difference	148
identify	46	find	399
fundamentally	50	basically	171
distinct	50	separate	79
examine	33	look at	399
ancient	69	older	660
derived	39	come from	630
inhabitants	13	residents	36
harmless	5	safe	58
tract	17	system	416
frequently	91	often	368
thoroughly	40	completely	110
contains	60	carries	125
extremely	62	very	796
condensed	9	compact	12
contain	60	have	3941

Words Substituted in the Computer Passages

Original		Substitution	
WORD	FREQUENCY	WORD	FREQUENCY
automatically	40	by itself	304
speed	83	rates	209
computation	7	calculation	35
transfers	38	moves	171
generated	11	produced	90
transforms	38	changes	240
briefly	73	for a moment	246
examine	33	look at	399
familiar	72	known	245
message	64	communication	67
converts	20	changes	240
speech	61	words	274
converts	20	changes	240
enable	23	let	384
slightly	83	somewhat	127
distorted	11	changed	240
reproduction	6	copy	38
transforming	38	changing	240
converts	20	changes	240
speech	61	words	274
speech	61	words	274
details	72	particulars	179
speech	61	words	274
converted	20	changed	240
appropriate	68	right	613
convert	20	change	240
correct	52	right	613
recreate	1	produce again	90
enable	23	let	384
comparison	71	contrast	74
generates	11	produces	90
cables	7	wires	42

connecting	33	joining	65
sheets	45	pieces	129
converted	20	changed	240
cable	7	wire	42
corresponding	38	matching	41
corresponds	38	is like	1290
region	76	part	500
generated	11	produced	90
proper	95	right	613
retrieve	10	recall	39
appropriate	68	right	613
retrieve	10	recall	39
appropriate	68	necessary	222
designated	17	assigned	53
outcome	26	result	224
messages	64	communications	67
proper	95	right	613
finished	87	stopped	129

APPENDIX F

EIGHT VERSIONS OF ONE CELLS PARAGRAPH

Original

1. Cells have the ability to take in energy and to convert it from one form to another. The original source of energy for living systems on this planet is the sun. The chlorophyll-containing cells of green plants and of algae transform this radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms derive their energy by the oxidation of the products of photosynthesis. All life in this biosphere depends on the carefully controlled flow of energy from the sun through living cells back into the environment.

Word Frequency

1. Cells have the ability to take in energy and to change it from one form to another. The original producer of energy for living systems on Earth is the sun. The chlorophyll-containing cells of green plants and of algae change this radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms get their energy by the oxidation of the products of photosynthesis. All life in this biosphere is supported by the carefully controlled movement of energy from the sun through living cells back into the environment.

Sentence Length

1. Cells have the ability to take in energy. They also can convert it from one form to another. The original source of energy for living systems on this planet is the sun. The chlorophyll-containing cells of green plants and of algae transform this radiant energy to chemical energy. They do this by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms derive their energy by the oxidation of the products of photosynthesis. All life in this biosphere depends on a carefully controlled flow of energy. The energy flows from the sun through living cells back into the environment.

Sentence Structure

1. Cells have the ability to take in energy and to convert it from one form to another. For living systems on this planet, the original source of energy is the sun. The sun's energy is transformed by certain cells--the chlorophyll-containing cells of gree plants and of algae, that transform radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells, such as those of plants, animals and other organisms, derive their energy by the oxidation of the products of photosynthesis. In this biosphere, all life depends on energy, on the carefully controlled flow of energy--passing from the sun, moving through living cells, going back into the environment.

Word Frequency and Sentence Length

1. Cells have the ability to take in energy. They also can change it from one form to another. The original producer of energy for living systems on Earth is the sun. The chlorophyll-containing cells of green plants and of algae change this radiant energy to chemical energy. They do this by the process of photosynthesis. The nonphotosynthetic cells of plants, animals, and other organisms get their energy by the oxidation of the products of photosynthesis. All life in this biosphere is supported by a carefully controlled movement of energy. The energy moves from the sun through living cells back into the environment.

Word Frequency and Sentence Structure

1. Cells have the ability to take in energy and to change it from one form to another. For living systems on this planet, the original producer of energy is the sun. The sun's energy is changed by certain cells--the chlorophyll-containing cells of green plants and of algae, that change radiant energy to chemical energy by the process of photosynthesis. The nonphotosynthetic cells, such as those of plants, animals and other organisms, get their energy by the oxidation of the products of photosynthesis. In this biosphere, all life is supported by energy, by the carefully controlled flow of energy--passing from the sun, moving thorugh living cells, going back into the environment.

Sentence Length and Sentence Structure

1. Cells have the ability to take in energy. Moreover, they can convert it from one form to another. For living systems on this planet, the original source of energy is the sun. The sun's energy is transformed by certain cells. These are the chlorophyll-containing cells of green plants and of algae. Such cells transform radiant energy to chemical energy by the process of photosynthesis. Nonphotosynthetic cells may be present in plants, animals and other organisms. These cells derive their energy by the oxidation of the

products of photosynthesis. In this biosphere, all life depends on energy, on the carefully controlled flow of energy--passing from the sun, moving through living cells, going back into the environment.

Word Frequency and Sentence Length and Sentence Structure

1. Cells have the ability to take in energy. Moreover, they can change it from one form to another. For living systems on Earth, the original producer of energy is the sun. The sun's energy is changed by certain cells. These are the chlorophyll-containing cells of green plants and of algae. Such cells change radiant energy to chemical energy by the process of photosynthesis. Nonphotosynthetic cells may be present in plants, animals and other organisms. These cells get their energy by the oxidation of the products of photosynthesis. In this biospehre, all life is supported by energy, by the carefully controlled movement of energy--passing from the sun, moving through living cells, going back into the environment.

EIGHT VERSIONS OF ONE COMPUTER PARAGRAPH

Original

What corresponds to the magnetic tape of the tape recorder? It is the memory, which is the region in the computer where data and programs are stored for automatic use by the machine. As data and instructions come into the computer as electrical signals, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form in the right place in the memory. As results are generated, the CPU must make sure that the proper electrical signals are sent to the terminal to make it type out the results for the user.

Word Frequency

What is like the magnetic tape of the tape recorder? It is the memory, which is the part of the computer where data and programs are stored for automatic use by the machine. As data and instructions come into the computer as electrical signals, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form in the right place in the memory. As results are produced, the CPU must make sure that the right electrical signals are sent to the terminal to make it type out the results for the user.

Sentence Length

What corresponds to the magnetic tape of the tape recorder? It is the memory. The memory is the region in the computer where data and programs are stored. They are stored for automatic use by the machine. Data and instructions come into the computer as electrical signals. As they come in, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form. The information also should be stored in the right place in the memory. As results are generated, the CPU must see that the proper electrical signals are sent to the terminal. The electrical signals make the terminal type out the results for the user.

Sentence Structure

What corresponds to the magnetic tape of the tape recorder? It is the memory, the storage region of the computer where data and

instructions are stored for automatic use by the machine. The central processing unit (CPU, for short) is like the tape control of the tape recorder. As data and instructions come into the computer as electrical signals, the CPU must act on the information, making sure it is stored in properly coded form in the right place in memory. As results are generated, the CPU must see that the proper electrical signals are sent to the terminal, making it type out the results for the user.

Word Frequency and Sentence Length

What is like the magnetic tape of the tape recorder? It is the memory. The memory is the part of the computer where data and programs are stored. They are stored for automatic use by the machine. Data and instructions come into the computer as electrical signals. As they come in, the central processing unit (CPU, for short) must make sure that the information is stored in properly coded form. The information also should be stored in the right place in the memory. As results are produced, the CPU must see that the right electrical signals are sent to the terminal. The electrical signals make the terminal type out the results for the user.

Word Frequency and Sentence Structure

What is like the magnetic tape of the tape recorder? It is the memory, the storage part of the computer where data and instructions are stored for automatic use by the machine. The central processing unit (CPU, for short) is like the tape control of the tape recorder. As data and instructions come into the computer as electrical signals, the CPU must act on the information, making sure it is stored in properly coded form in the right place in memory. As results are produced, the CPU must see that the right electrical signals are sent to the terminal, making it type out the results for the user.

Sentence Length and sentence Structure

What corresponds to the magnetic tape of the tape recorder? It is the memory, the storage region of the computer. In memory, data and instructions are stored for automatic use by the machine. The central processing unit (CPU, for short) is like the tape control of the tape recorder. As data and instructions come into the computer as electrical signals, the CPU must act on the information, making sure it is stored in properly coded form in the right place in memory. As results are generated, the CPU must see that the proper electrical signals are sent to the terminal, making it type out the results for the user.

Word Frequency and Sentence Length and Sentence Structure

What is like the magnetic tape of the tape recorder? It is the memory, the storage part of the computer. In memory, data and instructions are stored for automatic use by the machine. The central processing unit (CPU, for short) is like the tape control of the tape recorder. As data and instructions come into the computer as electrical signals, the CPU must act on the information, making sure it is stored in properly coded form in the right place in memory. As results are produced, the CPU must see that the right electrical signals are sent to the terminal, causing it to type out the results for the user.

APPENDIX G

OUTLINE OF CELLS PASSAGE

I. Cells are the structural and functional units of life.
   A. The smallest living organisms are composed of single cells.
   B. The largest living organisms are made up of billions of cells.
      1. Each cell of the largest living organisms are made up of billions of cells.
      2. Each cell of the largest living organisms still lives a partly independent existence.
   C. It was realized that all organisms are composed of cells.
   D. This realization was one of the most important conceptual advances in the history of biology.
      1. The realization was important because it provided a unifying theme for the study of all living things.
      2. Even the most diverse organisms are remarkably similar.
         a. They are similar in physical organization.
         b. They are similar in biochemical properties.
         c. Organisms are similar when studied at the cellular level.
   E. Cell theory is closely related to Darwin's theory of evolution.
      1. Cell theory is not a theory at all but the observation of a fact.
      2. Cell theory was formulated early in the 19th Century.
         a. This was before the presentation of of Darwin's theory of evolution.
         b. The cell theory and Darwin's theory are both unifying concepts.
   F. The link between modern organisms and the first cells can be seen in the similarities among cells.
      1. We can see evolutionary history in the similarities among cells.

II. There are many different kinds of cells.
  A. Many different kinds are in our own bodies.
    1. More than 100 different and distinct types are in our own bodies.
  B. Many kinds of one-celled organisms are in pond water.
    1. In a teaspoon are several different kinds.
    2. In a whole pond are several hundred clearly different kinds.
  C. Plant cells are superficially different from our own.
  D. Insects have kinds of cells that are not found in plants or vertebrates.
  E. The first remarkable fact about cells is their diversity.

III. The Second remarkable fact is their similarity.
  A. Every cell is self-contained and at least partially self-sufficient.
  B. Every cell is bounded by an outer membrane--plasma membrane, plasmalemma, cell membrane.
    1. The outer membrane controls passage of materials in and out of the cell.
      a. This makes it possible for the cell to differ from its surroundings.
      b. Cells differ biochemically and structurally from their surroundings.
    2. The outer membrane has the same basic structure throughout the living world.
  C. Every cell has cytoplasm within the membrane.
    1. Cytoplasm includes a variety of formed bodies.
    2. Cytoplasm includes various dissolved and suspended molecules.
  D. Every cell has at least one chromosome.
    1. DNA encodes genetic characteristics in all types of cells.
    2. The genetic code is similar from bacterium to oak to man.
      a. This means that the genetic code was probably in existence 3 billion years ago.

IV. Even more striking are the similarities in functions of cells.
  A. Cells can take in energy and convert it.
    1. The sun is the original source of energy.
    2. Chlorophyll-containing cells transform radiant energy to chemical energy through the process of photosynthesis.

3. Other cells derive their energy by oxidizing the products of photosynthesis.
4. Life depends on the carefully controlled flow of energy--from sun to cells to environment.

B. Cells use energy to build and maintain themselves.
1. Inanimate objects fall apart, erode, vanish.
a. They are under the influence of the environment.
b. For example, a mountain gradually erodes.
2. Living things are able to grow and evolve.
a. Living things do not just maintain themselves.
b. They are under the influence of the environment.
3. The above is a relationship between energy and order.
4. It is one of the most interesting principles of modern biology.

C. Cells take in substances from the outside to maintain and build more structure.
1. The substances are called "building materials."
2. About 90 elements are found naturally on the Earth's surface.
a. Life uses 24 of the 90 elements.
b. Six comprise 99% of the bulk of living tissues.
3. Elements inside cells differ proportionally from those just outside.
a. Cells maintain a relatively stable internal environment.
(1) Although they constantly exchange materials with the environment.
(2) Internal environment is different from surroundings.

D. Cells reproduce themselves.
1. Cells pass on all their capacities to their daughter cells.

V. Two distinct types of cellular organization are prokaryotic and eukaryotic.
A. These are within already identified patterns of striking diversity and similarity.
B. Prokaryotic cells are to be examined here.
1. They are simpler than eukaryotic cells.
2. They are more ancient than eukaryotic cells.
C. Prokaryotes and eukaryotes are derived from

a Greek word, Karyon, meaning kernel or nucleus.
1. Prokaryotes are before the nucleus.
2. Eukaryotes are with a true nucleus.

3. Modern prokaryotes include bacteria and the blue-green algae.

VI. The bacterium E. coli is a good example of a modern prokaryote.
- A. They are very common bacteria.
- B. They are harmless.
- C. They inhabit the human digestive tract.
- D. They may be the most thoroughly understood living system.
  1. They are used in many biochemistry and and genetics studies.

VII. E. coli is simple in its general structure.
- A. It consists of a cell wall, membrane, cytoplasm.
- B. The DNA contains the genetic information of the cell.
  1. It consists of a single long molecule in the cytoplasm.
  2. It is in an extremely condensed form in the bacterial cell.
     a. If the DNA were full extended, it would be about 700 times longer than the entire cell.
  3. It is in the form of a circle--there are no ends to the molecule.
- C. Often two or even four molecules of DNA are in E. coli.
  1. This is because DNA may replicate before the cell divides.
  2. In a fast-growing culture, replication may get well ahead of cell division.

OUTLINE OF COMPUTER PASSAGE

I. A computer is a machine that can store instructions and data.
   A. Then it can automatically execute the instructions.
   B. It can execute them with electronic speed.
   C. The computer is of use to us, if
      1. We can feed instructions and data into the computer.
      2. We can get the results of its computations.
   D. The input device feeds the instructions and data into the memory of the computer.
   E. The output device transforms the results into a form the user can understand or use in some other way.

II. At each stage, the information is carried in a different form.
   A. To understand this, let us examine a tape recorder.
   B. A tape recorder is a system that can record sound on magnetic tape.
   C. Later, the tape recorder can play back what was recorded.

III. Consider the use of a tape recorder to record and play back a spoken message.
   A. The input device is a microphone.
      1. The microphone converts speech into electrical signals.
      2. The speech reaches the microphone as pressure waves in the air.
   B. The output device is a loudspeaker.
      1. The loudspeaker converts electrical signals into pressure waves in the air.
      2. The pressure waves enable the user to hear the original sound.
         a. The sound is at least a slightly distorted reproduction of the original sound.

IV. The transformation of information is called coding.
   A. Each form of information is called a code.
   B. The microphone converts speech from an

air-pressure code to an electrical signal code.

C. The loudspeaker works the other way--electrical signal code to a speech code.

D. Speech is stored on magnetic tape.

1. Speech is stored on tape as a pattern of magnetization.

2. The details of how speech becomes a magnetic code are not important.

a. What is important is that speech can be recorded on magnetic tape.

b. The code on the tape is neither pressure waves nor electric current.

E. During recording, the tape control's job is to convert electrical signals.

1. The tape control changes the electrical signals to the appropriate magnetization on tape.

F. During playback, the tape control's job is to convert the magnetization on the tape to the correct pattern of electrical signals.

1. This is done to make the loudspeaker recreate the recorded sound.

V. Sound is the medium of input and output to and from the recorder.

A. Another kind of input is control signals.

1. Examples are PLAY, RECORD, REWIND, FAST FORWARD, and STOP.

B. Control signals enable the user to make decisions.

1. The user may decide just what the machine will record.

2. The user may decide what and when the recorder will play back.

VI. We can now see how a computer is used in interactive mode.

A. The tape recorder was an example used for comparison.

B. In interactive mode, the user gets results as soon as the computer generates them.

C. The user can type in new information at any time in interactive mode.

1. If it is an input instruction, the CPU will read information into the memory.
2. If it is an output instruction, the CPU will send the appropriate information to the terminal.
3. If it is an operation instruction, the CPU will carry out several steps:
   a. It will retrieve the necessary data from memory.
   b. It will carry out the operation (adding two numbers together, for example).
   c. If appropriate, it will store the results in a particular place in memory.
4. An instruction may call for a test.
   a. If so, the CPU will perform that test.
   b. Then it will go to the instruction specified by the outcome of the test.

XI. The user types in different kinds of control signals at the terminal.
   A. Control signals are messages to the computer.
      1. Control signals are neither data nor part of a program.
      2. Control signals tell the computer things.
         a. Expect data next, so store it in such-and-such part of memory.
         b. Expect a program in FORTRAN next, so use the FORTRAN translator when executing the program.
         c. The program and data have been entered, so start executing the program to process the data.
   B. The computer usually does not understand English.
      1. The control signals are written in a special programming language.
      2. The language is called a job control language.

VII. The user interacts with the computer through a device called a terminal.
  A. The terminal looks like a typewriter.
    1. But a terminal has cables linking it to a computer.
    2. Also, it is fed by a continuous role of paper.

VIII. As the user types, he gets information typed on the paper and sends information to the computer.
  A. The typed symbols are sent to the computer after they are converted to electrical signals.
    1. The electrical signals are sent along a cable to the computer.
  B. The terminal types computer output.
    1. After it first receives electrical signals from the computer.
    2. Then it converts the electrical signals to the corresponding symbols which are typed on the paper in the terminal.
  C. The functions of the terminal are like those of the microphone and loudspeaker of the tape recorder.

IX. The computer's memory corresponds to the magnetic tape of the tape recorder.
  A. The memory is a region of the computer.
    1. Data and programs are stored in memory for automatic use by the machine.
  B. The central processing unit converts information.
    1. The information enters it as electric signals from the terminal.
    2. The CPU changes the electric signals to another code.
    3. The CPU sends the code to the right place in memory.
  C. When results are generated, the CPU sends the proper electrical signals to to the terminal.
    1. The CPU makes the terminal type out results for the user.

X. The CPU is like the tape control of a tape recorder, but does more.
  A. A computer does not simply store and retrieve information.
  B. The computer also follows the instructions of a program.
    1. It follows instructions to process the information.
  C. The CPU takes one instruction at a time out of memory.

APPENDIX H

Number_____Name_____School_____

Form_____

RECALL QUESTIONS--Introduction to the Cell

Directions: How exactly can you remember what you read? Briefly answer each of the following questions according to what you remember from the text.

1. What are the smallest living organisms made of?

2. What was one of the most important concepts or ideas in the history of biology?

3. At the level of the cell, what otherwise different things are very similar to each other?

4. In what century was the cell theory put together?

5. The cell theory was put together before what other theory?

6. What has at least 100 clearly different types of cells?

7. What is every cell enclosed by?

8. Where is cytoplasm located?

9. What is dissolved or suspended inside the cell?

10. Since the genetic code is similar among organisms, how many years ago was it probably in existence?

11. From what place does energy first come?

12. For what purpose do cells make or take in energy?

13. Under the influence of the environment, what slowly happens to nonliving things?

14. Under the influence of the environment, living things are able to grow and evolve, not just do what?

15. Living systems use 24 of how many elements found naturally?

16. Prokaryotic and eukaryotic are two distinct types of what?

17. What are defined as being before the nucleus?

18. What does E coli have that may number between 1 and 4?

AFTER YOU HAVE FINISHED THESE QUESTIONS: Be sure to review your answers to check for mistakes and to make sure that they are clear. Then begin work on the next passage.

Number_____Name_____School_____

Form_____

RECALL QUESTIONS--Moving and Storing Information

Directions: How exactly can you remember what you read? Briefly answer each of the following questions according to what you remember from the text.

1. What does a computer do?

2. What does the output device of the computer do to the results before making them available to the user?

3. What is the input device of a tape recorder called?

4. The output device of a tape recorder changes electrical signals to what (that we hear as sound)?

5. What is any form of information called that has been changed to another form?

6. On what material can sound be stored?

7. What is stored in a tape recorder as neither pressure waves nor electric current?

8. During playback, what is changed by the tape control?

9. In interactive mode, what can the user do at any time?

10. What input and output device is attached to the computer by cords?

11. In what part of the computer are data and programs stored for use by the computer?

12. The central processing unit (CPU) acts like what part of the tape recorder?

13. In what changed form do data and instructions enter the CPU from the input device?

14. What important additional task does the CPU perform that a similar device on the tape recorder does not perform?

15. From where might the CPU get data if it receives an operation instruction?

16. If the CPU performs a test, what has it just received?

17. What is meant by control signals that the user might type in?

18. After the user has completed typing in a program, what does the user have to tell the computer to use--in order to execute the program?

AFTER YOU HAVE FINISHED THESE QUESTIONS: Be sure to review your answers to check for mistakes and to make sure that they are clear. Then begin work on the next passage.

APPENDIX I

Number_____ Name_____ School_____

Form_____

INTEREST SURVEY

Before you take the comprehension test, please rate the passage on the following scales. For each item, place an X in the box that most nearly reflects your feeling about the passage.

Example:

good				X				bad

Because the above person marked the center box, s/he felt the passage was neither good nor bad. If s/he had marked a box closer to the good, that would mean s/he felt the passage was more good than bad. If s/he had marked a box closer to the bad, that would mean s/he felt it was more bad than good. Rate how you feel about the passage on the following scales:

interesting								uninteresting
boring								fascinating
breezy								dry
tedious								lively
engaging								unengaging
dull								animated
wearying								exhilarating
unexciting								exciting

How much did you already know about this subject before you read?

almost nothing								almost everything

How interested were you in this subject before you read the passages?

almost no interest								very great interest

How much information in this passage was new to you?

almost none of it								almost all of it

APPENDIX J

DIRECTIONS

Please do not begin reading until you are told to do so. You have been given two textbook passages to read. Each is about four pages long. After you have read a passage, you will find an interest survey for showing your level of interest in what you were reading. After you fill it out, you will find 18 short-answer questions about the passage to answer.

Before you read, write your name at the top of the page. Then mark down your beginning time as shown by the digital clock. For the first passage, mark 0:00 (demonstrate on chalkboard) at the top of your paper in the place indicated on the page (demonstrate). When you finish reading the passage, mark your ending time on the last page of the passage (demonstrate). The directions on the pages will remind you to do so. The digital clock only displays up to ten minutes, and then it starts over. When it does start over, I will place this card saying "10+" on top of the clock. If you see this number, write 10+ whatever the clock says on your paper. Later, I will place 20+ or 30+ cards on the clock. Don't forget to copy these numbers when recording beginning or ending times on your two passages (demonstrate on chalkboard and answer questions).

After you read a passage and record your ending time, raise your hand so that I may come around to collect your passage. You may begin filling out the interest survey while you are waiting for me. Do not

be disturbed if other students finish before you do, as the passages vary in length and are not exactly the same.

Read the passages very carefully because the short-answer questions are not easy. I will be back next week on this day to report the results to you. Are there any other questions?